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PB-251 307

Assessment of Industrial Hazardous Waste Practices, Organic Chemicals, Pesticides, and Explosives Industries

TRW Systems Group

Prepared For
Environmental Protection Agency

April 1975

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The objectives of this study were to determine, for the manufacturers of industrial organic chemicals, pesticide preparations and formulations and explosives: 1) the quantities and geographic distributions of land-destined hazardous wastes, 2) present practices for treatment and disposal of land-destined hazardous wastes, 3) commercial control technology which could be applied to reduce the hazards presented by disposal of such wastes, and 4) the cost of present practices and the applicable commercial technology.

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This final report (SW-118c) describes work performed for the Federal solid waste management programs under contract no. 68-01-2919 and is reproduced as received from the contractor

U.S. ENVIRONMENTAL PROTECTION AGENCY
1976

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PREFACE

This report summarizes the results of a study of land-destined hazardous wastes and the assessment of treatment and disposal practices of the organic chemicals, pesticides, and explosives industries conducted for the Environmental Protection Agency. The project is deeply indebted to the EPA Project Officers, Messrs. Sam Morekas and Timothy Fields, Jr., of the Hazardous Waste Management Division, for their continuing advice and guidance during the entire term of the study. Thanks are also due to the management and other staff members of the Office of Solid Waste Management Programs, Hazardous Waste Management Division, who reviewed program progress, assisted with constructive suggestions, and coordinated this study with the related projects in other industry categories for which they were responsible.

This project would not have been accomplished without the key information furnished by the participating private companies, by the Armed Services, and by other Federal and State Agencies. Our thanks are conveyed, hereby, to the management and staffs of all of the cooperating companies listed in Table A-1* for the vital assistance they furnished. The Armed Services and Federal Agencies made especially noteworthy contributions to the accomplishment of this study, and we wish to express our gratitude for this help to the officers and staff, Headquarters, Edgewood Arsenal, and Picatinny Arsenal, U.S. Army Armament Command; the U.S. Army Materiel Command Installations and Services Agency; the U.S. Army Environmental Hygiene Agency; the Alcohol, Tobacco and Firearms Division, Internal Revenue Service, Department of the Treasury; the Social and Economic Statistics Administration, Bureau of the Census, Department of Commerce; the U.S. International Trade Commission, Department of the Treasury; and the U.S. Navy Naval Sea Systems Command. The cooperation of the National Agricultural Chemicals Association is gratefully acknowledged.

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*See Appendix A

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1. INTRODUCTION

This report is the result of a study commissioned by the U.S. Environmental Protection Agency for the "Assessment of Industrial Hazardous Waste Practices — Organic Chemicals, Pesticides and Explosives Industries." Concurrently, the U.S. Environmental Protection Agency is pursuing similar studies of other industry categories. These programs are intended to provide the U.S. EPA with detailed and pertinent information on the generation, management, treatment, disposal and costs related to wastes considered to be "potentially hazardous."

Throughout this report, wherever the terms "hazardous wastes" or "potentially hazardous wastes" are used, or where classification of waste components into "moderately dangerous" or "highly dangerous" has been performed, it should be kept in mind that no final judgments are intended as to such classification. It is recognized and understood that additional information will be required as to the actual fate of such materials in a given "disposal" or "management" environment, before a final definition of "hazardous waste" evolves and is used. As an example, for certain of the waste streams identified in this report, the U.S. EPA is currently supporting other studies designed to investigate leaching characteristics in various soil and moisture conditions.

The objectives of this study were to determine, for the manufacturers of organic chemicals (covered by Standard Industrial Classification (SIC) 286), pesticide preparations and formulations (SIC 2879) and explosives (SIC 2892):

- The quantities and geographic distributions of those land-destined hazardous wastes generated in 1973, and projected for 1977 and 1983.
- Present practices for treatment and disposal of land-destined hazardous wastes.
- Commercial control technology which could be applied to reduce the hazards presented by disposal of selected examples of such wastes.
- The costs of present practices and the applicable commercial technology as implemented upon the selected examples.

To meet these objectives, it was necessary that the contractor perform five major tasks: Characterize the industries, characterize the land-destined hazardous waste streams; identify treatment and disposal technologies; perform cost analyses on implementation of the treatment and disposal technologies; and document the findings of the study in a final report.

This final report documents the findings of the study performed by TRW under Contract 68-01-2919, and is presented in the following seven sections and two appendices:

- Section 2 — EXECUTIVE SUMMARY

  Figures, tables, and a brief narrative interpretation, highlighting the key data and estimates developed.

- Section 3 — METHODOLOGY

  A summary of the techniques employed for deriving the quantitative figures presented on the industries, their hazardous waste streams, treatment and disposal technology, and costs.

- Section 4 — INDUSTRY CHARACTERIZATION

  Statistical summaries by state, U.S. EPA region, and the nation of the products, numbers of plant sites, production capacities, processes and quantities manufactured annually for each product group/industry.

- Section 5 — WASTE CHARACTERIZATION

  Selected typical process flow diagrams, mass balances, and plant and hazardous waste stream descriptions; estimates for 1973, and projections for 1977 and 1983, summarized statistically by geographic area, of land-destined process waste discharge, hazardous process waste discharge, and hazardous component content; and listings of the highly dangerous waste components for each product group.

- Section 6 — TREATMENT AND DISPOSAL TECHNOLOGY

  Summaries and analyses of participant company/agency data on treatment and disposal practices; Level I, Level II, and Level III technology identification for land-destined hazardous waste streams from the selected typical plants; discussions of prevalent land-based technology, including off-site contractor processing.

- Section 7 — COST ANALYSIS

  Costs per ton of product and costs per ton of waste for treatment and disposal of hazardous wastes at the selected typical plants using Level I, II and III technology.

- Section 8 — REFERENCES AND BIBLIOGRAPHY

- APPENDIX A

  Details of the methodology used in deriving the data contained in this report.

- APPENDIX B

  Injection Well Act, State of Texas; Waste Disposal to Land Regulations, State of California; Hazardous Waste Law and Hazardous Waste Regulations, State of California.

- APPENDIX A

  Details of the methodology used in deriving the data contained in this report.

- APPENDIX B

  Injection Well Act, State of Texas; Waste Disposal to Land Regulations, State of California; Hazardous Waste Law and Hazardous Waste Regulations, State of California.

2. EXECUTIVE SUMMARY

This industry study is one of a series by the Office of Solid Waste Management Programs, Hazardous Waste Management Division. The studies were conducted for information purposes only and not in response to a Congressional regulatory mandate. As such, the studies serve to provide EPA with: (1) an initial data base concerning current and projected types and quantities of industrial wastes and applicable disposal methods and costs; (2) a data base for technical assistance activities; and (3) a background for guidelines development work pursuant to Section 209, Solid Waste Disposal Act, as amended.

The definition of "potentially hazardous waste" in this study was developed based upon contractor investigations and professional judgment. This definition does not necessarily reflect EPA thinking since such a definition, especially in a regulatory context, must be broadly applicable to widely differing types of waste streams. Obviously, the presence of a toxic substance should not be a major determinant of hazardousness if there were mechanisms to represent or illustrate actual effects of wastes in specified environments. Thus, the reader is cautioned that the data presented in this report constitute only the contractor's assessment of the hazardous waste management problem in these industries. EPA reserves its judgments pending a specific legislative mandate.

There are approximately 2,200 plant sites (operated by hundreds of private companies) spread over the United States, engaged in the manufacture of organic chemicals, pesticides and explosives. Each of these plant sites produces at least one, and usually more commodities, classified under SIC's 286, 2879 and 2892, and discharges process wastes from its production lines. This study reports on the process wastes in 1973 that went (or will go in 1977 and 1983) to land disposal: How much, what, and where; what was done in industry sample plants for treatment and disposal; what's the best that was done or the best that can be done commercially; and how much the treatment and disposal methods cost. "Disposal to the land" as employed in this study includes deep sea disposal, deep well disposal, lagooning, landfill, burial, and incineration.

A methodology emphasizing mixtures of hard facts and estimates at the individual production line and commodity level was developed to produce the reported results. The exact figures for production at each plant, reported to the various Federal Agencies, are privileged information protected by Congressional legislation and company proprietary information rules. The exact quantities of process wastes discharged to land at each plant for each process – how much of what – were in the majority of cases, unknown because the streams were not monitored adequately or with sufficient frequency. Therefore, we estimated waste quantities based on our assessment of production distribution, process technology, literature data, and industry and Government agency furnished data. The bulk of the estimates (for the organic chemicals, technical pesticides and Government Owned Contractor Operated (GOCO) explosives industries) were for each product at each plant in the study. The remaining estimates (for the pesticides preparations and private explosives industries) were the total for all plants in each industry in each state. The results were integrated to yield the data presented.

Criteria based on 1973 production rates were imposed to limit the number of organic chemicals and technical organic pest control chemicals for which estimates were made. In summary, the study examined:

- Individual organic chemicals whose production in the United States was 10 million pounds per year or more.
- Technical organic pest control chemicals for which United States production was 1 million pounds per year or more.

The production in 1973 for chemicals which met the above criteria constituted approximately 90 percent of the tonnage of organic chemicals and technical organic pest control chemicals manufactured in the United States.

The Standard Industrial Classification (SIC) system splits the pesticides industry into two parts – one under SIC 28694 (pesticides and other synthetic organic chemicals) and the other, pesticides preparations and formulations, under SIC 2879. For clarity they have been treated as a single heading, "The Pesticides Industries," in this summary. To avoid redundancy the data reported for the organic chemicals industry in this summary excludes SIC 28694.

2.1 INDUSTRY CHARACTERIZATION

The five major industries examined were:

SIC 2861	Gum and Wood Chemicals Industry
SIC 2865	Cyclic Crudes and Intermediates Industry
SIC 2869	Industrial Organic Chemicals NEC* Industry
SIC 2879	Pesticides Industries (Including SIC 28694)
SIC 2892	Explosives Industry

The estimated 87 million metric tons of product manufactured by these five major industries were subdivided into 20 product groups and several thousand individual commodity products. This summary reports by major industry.

The industrial organic chemicals (64 million metric tons) and the cyclic crudes and intermediates (just under 19 million metric tons) industries manufactured the greatest volume of product during 1973. Texas, with 35 million metric tons, and Louisiana, with 14 million metric tons, led the states in production. Table 2-1 presents production data for calendar year (CY) 1973.

This study provides estimates and data for 1,908 plant sites** in the United States engaged in the manufacture of organic chemicals, pesticides and explosives. The term plant site has been used to identify each facility where one or more of the commodities (organic chemicals, pesticides or explosives) covered in this study are manufactured. A given plant site, by this definition, may contain any number of processes (in some cases, 30 or more) each producing a different commodity.

Texas had the greatest total number of plant sites (172) for the five major industries covered in this study. New Jersey had the second largest number of plant sites (152), and California with 142 plant sites was third nationally.

There were 765 organic chemical plant sites*** which met the criteria for inclusion in this study given on page 2-2. New Jersey, Texas and Ohio ranked first, second and third in number of organic chemical plant sites***.

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*NEC—Not elsewhere classified

**This number includes only those plants meeting the production criteria stated on p. 2-2, and hence is less than the 2,200 plant sites referred to on p. 2-1.

***Excluding technical organic pest control chemical manufacturing sites (SIC 28694).

Table 2-1. Production, Thousand Metric Tons, by Standard Industrial Classification, for CY 1973 for the Organic Chemicals[1], Pesticides[2] and Explosives Industries

EPA Region	State	Organic Chemicals[3]			Pesticides[4]	Explosives[5]	
		SIC 2861	SIC 2865	SIC 2869 [3]	SIC 28694/2879	SIC 2892	Total[7]
4	Alabama	97	660	294	90	87	1,200
10	Alaska			290		2	290
9	Arizona				3	85	88
6	Arkansas			129	34	8	170
9	California		425	1,985	215	30[6]	2,700
8	Colorado		2	2	39	10	53
1	Connecticut		0.5	110	12	9	130
3	Delaware		333	433	3	0.06	770
3	District of Columbia						
4	Florida	282	292	617	82	21	1,300
4	Georgia	49	118	279	53	15	510
9	Hawaii				3	1	4
10	Idaho				3	5	8
5	Illinois		547	1,619	80	161	2,400
5	Indiana		173	457	17	55	700
7	Iowa			298	57	14	370
7	Kansas		59	114	14	4	190
4	Kentucky		75	1,876	3	155	2,100
6	Louisiana	88	2,279	11,956	84	2	14,000
1	Maine					2	2
3	Maryland		374	131	22	7	530
1	Massachusetts		4	150	20	3	180
5	Michigan		871	337	46	26	1,300
5	Minnesota		23		15	52	90
4	Mississippi		107	70	60	1	240
7	Missouri		62	139	99	12	330
8	Montana			36	7	3	46
7	Nebraska			18	10	1	29
9	Nevada		32		7	12	51
1	New Hampshire			11	3	1	15
2	New Jersey		1,320	1,435	108	3	2,900
6	New Mexico					29	29
2	New York		96	277	67	12	450
4	North Carolina	14	359	376	40	12	800
8	North Dakota					0.4	0.4
5	Ohio		299	997	60	22	1,400
6	Oklahoma			37	10	16	63
10	Oregon		23	451	20	6	500
3	Pennsylvania		1,099	827	51	130	2,100
2	Puerto Rico		645	7,471			8,100
1	Rhode Island		1	15		0.4	16
4	South Carolina	29	210	246	30	2	520
8	South Dakota					1	1
4	Tennessee		350	879	53	187	1,500
6	Texas	71	6,718	28,350	173	21	35,000
8	Utah		57		3	18[6]	78
1	Vermont					0.8	0.8
3	Virginia		222	234	13	167	640
10	Washington	41	113	69	33	7	260
3	West Virginia		697	1,297	33	70	2,100
5	Wisconsin		40	54	23	39	160
8	Wyoming					5	5
NATIONAL TOTALS		670	18,682	64,368	1,791	1,657	87,000

[1] Production figures based on those organic chemicals whose national production in 1973 was > 10 million pounds.

[2] Production figures based on those technical organic pest control chemicals (SIC 28694) whose national production in 1973 was > 1 million pounds, plus estimates based on the "1972 Census of Manufacturers" for SIC 2879.

[3] Excluding SIC 28694, technical organic pest control chemicals.

[4] Including SIC 28694, technical organic pest control chemicals.

[5] Based on data for CY 1973 consumption by state from "Mineral Industry Survey," U. S. Bureau of Mines and data from the U. S. Army Armament Command.

[6] Excluding certain propellant compositions.

[7] All production estimates in this column are rounded off to the nearest two significant figures and therefore may not agree with the State and National totals in the body of the text.

with 121, 89 and 55 sites, respectively. Total organic chemical production (excluding technical organic pest control chemicals) was just under 84 million metric tons. Texas and Louisiana had the highest levels of organic chemical production.

The three major industries comprising the organic chemicals industry were divided into 12 major product groups, for the purpose of estimating plant size for each product group at each site. Roughly 65 percent of the product group-plant site combinations had an aggregate production capacity of less than 100 metric tons per day. Only one combination in 16 had an aggregate production capacity of 1,000 or more metric tons per day.

The processes employed in the organic chemical industry were divided into 34 process types, on the basis of the process chemistries involved in the manufacture of the individual commodities. There were approximately 2,400 chemical product-plant site combinations for the organic chemical industry* (each representing a production line which manufactured an organic chemical commodity) classified by process type. The most numerous process type was "Multi-step synthesis," used at 324 plants.

The pesticides industries (SIC 28694 and SIC 2879) had 522 plant sites. The national total number of production sites for the technical pesticide manufacturing industry (SIC 28694) was 134. The pesticide formulating industry (SIC 2879) had 388 sites. California and Texas had the greatest number of plants producing pesticides and formulations, 62 and 44 respectively. Total pesticide and pesticide formulation production was slightly under 1.8 million metric tons. Of this total, just over 0.5 million metric tons were technical organic pest control chemicals (SIC 28694) and approximately 1.3 million metric tons were pesticide preparations and formulations (SIC 2879). California and Texas led the nation in overall pesticide production.

None of the technical organic pest control chemical plants had production capacity in excess of 100 metric tons per day. Approximately 60 percent of the technical organic pest control plants had production capacities less than 10 metric tons per day. Data on the production capacities of individual pesticide formulation plants was not available.

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*Excluding technical organic pest control chemicals.

There were 11 process types used by the pesticides industries, 8 by the technical organic pest control industry, and three by the pesticide formulation plants. The most numerous process type for the technical pesticide plants was "Multi-step synthesis," used at 92 per cent of the plant sites.

The explosives industries (SIC 2892) had 621 plant sites; of this total, 586 were private explosives industry (SIC 28921) sites, and 35 were Government Owned Contractor Operated (GOCO) plants (SIC 28922). Pennsylvania, California and Texas had the greatest numbers of explosives industries (SIC 2892) plants, with 75, 45, and 39, respectively. Total explosives production was slightly less than 1.7 million metric tons. GOCO plants produced just over 0.4 million metric tons of explosives; the private explosives industry produced the remainder (1.25 million metric tons). Tennessee and Virginia produced the greatest quantities of explosives, with totals of 187,000 metric tons and 167,000 metric tons, respectively.

The majority of the basic information used for the characterization of the organic chemicals industry was obtained from three sources: The preliminary reports for 1973 by the United States International Trade Commission (formerly Tariff Commission) on United States production and sales of synthetic organic chemicals,(3) the Stanford Research Institute "1974 Directory of Chemical Producers — United States of America,"(11) and the organic chemical companies listed in Table A-1, Appendix A. The article by O. Johnson, "Pesticides '72",(42) in Chemical Week was the fourth major information source used for characterizing the technical organic pest control chemicals industry, in addition to the three sources just cited. For the characterization of the pesticides preparations and formulations industry, the major information sources were the preliminary report for 1972 on agricultural chemicals (SIC 2879) of the Bureau of the Census,(5) a communication on the geographical distribution of pesticide manufacturing establishments from the Bureau of the Census,(6) and the pesticides manufacturing companies listed in Table A-1, Appendix A. The U.S. Army Armament Command furnished all the information used for characterizing the GOCO plants. The major information sources for the characterization of the private explosives industry were the Bureau of Mines report on apparent consumption of industrial explosives and blasting agents in 1973,(15) and a private communication from the Alcohol, Tobacco and Firearms Division of the Internal Revenue Service on explosive manufacturers.(16)

2.2 WASTE CHARACTERIZATION

Twenty-one hypothetical plants, each using a single process, were selected as "typical" for this study in order to characterize the waste streams discharged to land by the plants of the organic chemicals industry. The processes examined are used for the production of the following organic chemicals: Perchloroethylene nitrobenzene, 1-chloro-4-nitrobenzene, chlorinated solvents (chloromethanes), chlorobenzene, ethyl chloride, epichlorohydrin, ethanolamines, furfural, benzoyl peroxide, pyridines (2-methyl, 5-ethyl pyridine and α-picoline), fluorocarbons, toluene diisocyanate, vinyl chloride monomer, methyl methacrylate monomer, acrylonitrile, maleic anhydride, lead alkyls, α-chlorotoluene, methylene chloride, and 1,1,1-trichloroethane.

The bases for the selection of the processes were the significance of their products and process waste streams, the national production volume for the products of the processes, and the industrial importance of the chemical product groups represented. The individual national production volumes for nineteen of the organic chemicals produced by the hypothetical plants was greater than 23,000 metric tons (50 million pounds) per year. The twenty-one products selected constituted 9 percent by weight of the total production of the organic chemicals industry. Because the processes selected generated far more waste per unit of product than the average for the organic chemicals industry, the total process wastes (dry basis) discharged to land by plants producing the twenty-one products represent about 52 percent by weight of the total land-destined process wastes (dry basis) of all United States organic chemicals plants. Eighteen of the processes discharge hazardous process wastes (as described later in this section) to land disposal. Two of the three processes which currently discharge no hazardous wastes to land will probably be required by the Federal Water Pollution Control Act Amendments to provide land-based treatment and disposal methods for hazardous wastes currently present in their industrial outfalls.

Emphasis has been placed in the characterization of wastes from the pesticides industries on the discharges and technologies of the technical pesticides manufacturing industry (SIC 28694). The reasons are twofold: First, and most important, are the much higher quantities of hazardous wastes anticipated from technical pesticides plants, as opposed to the relatively low quantities estimated for pesticides formulations and preparations production. Second is this study's lack of access to quantitative data other than gross national statistics on pesticides formulations and preparations production. Detailed information on the annual production of each formulation at each plant site was treated as proprietary by the companies involved and was not available from trade publications.

Because of the very sensitive nature of the pesticide manufacturing and formulation industries, very little information is available on specific details of production and formulation operations for a large number of individual pesticides and pesticide preparations. Most manufacturers and formulators are extremely reluctant to reveal technical process data.

Five typical technical pesticide processes were selected for presentation of process flow diagrams, mass balances, and waste stream descriptions, to characterize the industry waste streams sent to land. Combined total production for the five technical pesticides selected was estimated to constitute approximately 26 percent of the national total for production of all technical organic pest control chemicals. Combined total process wastes discharged to land (dry weight basis) for the five technical pesticides was estimated to constitute 19 percent of the national total dry weight of process wastes discharged to land by all technical organic pesticides plants. The five technical pesticides selected were, therefore, considered as adequately representative of product group SIC 28694. The five technical pesticides selected were: Aldrin, atrazine, trifluralin, parathion and methyl parathion, and malathion. Each of the five technical pesticide production processes discharged hazardous wastes (as defined later in this section) to land disposal.

Explosives-containing wastes originate from the manufacture of basic explosives, from explosives formulation, and from loading, assembly, and packing (LAP) operations. The processes selected to characterize the wastes of the explosives industry were selected as typical of each of the three sources. The process and waste stream descriptions were: For basic explosives, trinitrotoluene, nitrocellulose, nitroglycerin, RDX, and HMX; for explosives formulation, Composition B, dynamites and a double-base propellant; and for LAP operations, flow diagrams and mass balances for a typical LAP plant.

The estimated total quantity (dry weight basis) of process waste streams discharged to land-based disposal in CY 1973 by the three industries examined in this study was 2.2 million metric tons. Process waste stream discharge to land was highest on a dry weight basis in 1973 in Texas and Louisiana with 916,000 and 268,000 metric tons, respectively. The organic chemicals industry total process wastes discharged to land (dry weight basis, in 1973 are estimated as 2.01 million metric tons. The pesticides industries and the explosives industries sent (estimated, dry weight basis) 175,000 and 21,000 metric tons, respectively, of total wastes to land disposal in 1973.

The dry weight basis has been used throughout this study as the baseline for all estimates. The majority of the process waste streams sent to land disposal by the organic chemicals, pesticides, and explosives industries are relatively low in water content or are nonaqueous. Based on the survey data for the waste streams of the organic chemicals industry developed during this study (described in Sections 2.3 and 6.2), 87 percent of the total number of process waste streams in 1973 were nonaqueous. Thirteen percent of the total number of process waste streams were treated by deep well, evaporation pond, and lagooning disposal techniques, which are "wet" methods. Because of the large quantity of water used by these wet methods, the wet-basis figures for the total process wastes of the organic chemicals industry for 1973 are estimated on the basis of the sample cited as 6.4 million metric tons.

The survey ratio of 3.17 between actual tons (wet basis) and dry basis tons was used above as a conversion factor for estimating wet-basis ("actual") process waste quantities from the data for dry-basis process wastes sent to land disposal by the organic chemicals industry. As discharged from the process, the wastes produced by the organic chemicals industry generally contain little or no water. To facilitate hydraulic transport for disposal by deep well injection, lagooning and evaporation pond, and in cases where the method of ultimate disposal is deep well injection, water is added to the wastes. The ratio of 3.17 between the wet basis and dry basis thus reflects the addition of water for hydraulic transport and/or pre-disposal treatment at some plant sites. Because the waste hydraulic transport and pre-disposal treatment characteristics in the pesticides and private explosives industries are generally similar to those for the organic chemicals industry, the ratio of 3.17 was also assumed to be applicable to the pesticides and private explosives industries. Wastes from GOCO explosives industry contain little or no water, and are disposed of by incineration (open burning). For these plants, the actual tons (wet basis) and dry basis tons were therefore assumed to be equal. For 1973, total wet-basis process wastes discharged to land are estimated as 554,000 metric tons for the pesticides industries, and 25,000 metric tons for the explosives industries. Total "actual" (wet-basis) process wastes discharged to land disposal in 1973 by the industries covered in this study are estimated as 7.0 million metric tons.

The total quantity of process waste streams which will be sent to land disposal by the organic chemicals industry is estimated for 1977, on a dry weight basis, as 3.43 million metric tons. On the basis used above for 1973 data, the wet-basis figures estimated for 1977 for the land-destined process wastes of the organic chemicals industry are 10.9 million metric tons. Analogous estimates for the organic chemical industry wastes for 1983 are 3.66 million metric tons on a dry weight basis, and 11.6 million metric tons on a wet basis.

Estimates of the land-destined process waste streams for the pesticides industries for 1977 and 1983 are 216,000 and 238,000 metric tons, respectively, on a dry weight basis. The wet basis figures for 1977 and 1983 are 684,000 and 753,000 metric tons, respectively.

Currently there is no valid basis for estimating the process waste discharge to land disposal for 1977 and 1983 for the GOCO explosives plants because of the extreme unpredictability of munition production. Assuming that the production of explosives at the GOCO plants in 1977 and 1983 will remain at the 1973 level, and that there will not be significant changes in the waste generation factors for the production of explosives, the estimates of total process wastes which will be discharged to land in

1977 and 1983 by the organic chemicals, pesticides and explosives industries, are, therefore, as follows:

1977	(dry basis) —	3.67 million metric tons
	(wet basis) —	11.6 million metric tons
1983	(dry basis) —	3.92 million metric tons
	(wet basis) —	12.4 million metric tons

The process waste streams have been divided into two major categories— "hazardous wastes" and "other wastes" —on the basis of the characteristics of their components and the following waste stream criteria:

- Potential to cause human death, injury, illness or harm to wildlife/beneficial biota.*
- Possible paths for harmful entry into the environment, through the entire cycle of waste management.**

Waste streams which meet these criteria, and contain components classified as "moderately dangerous" or "highly dangerous" are categorized for this study as "hazardous wastes." Components are classified in accordance with their health hazard (mammalian toxicity), fire and explosive hazard (flash point and explosiveness), aquatic toxicity, and reactivity. Examples of the methodology employed in this study to define "moderately dangerous" and "highly dangerous" components are mammalian toxicity (expressed as LD_{50}, oral) between 50 and 500 mg/kg for "moderately dangerous," and less than 50 mg/kg for "highly dangerous." A detailed description of the classification system is given in Appendix A.

The total dry basis tonnage estimated for hazardous waste streams discharged to land disposal in 1973 — 2.15 million metric tons — is approximately 98 percent of the "dry tons" for all process discharges to land disposal by the organic chemicals, pesticides and explosives industries. Virtually all land-destined waste streams from the three industries contain one or more components classified as "hazardous."

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*See Table 3-1 for the quantitative basis used to rate components of the waste streams.

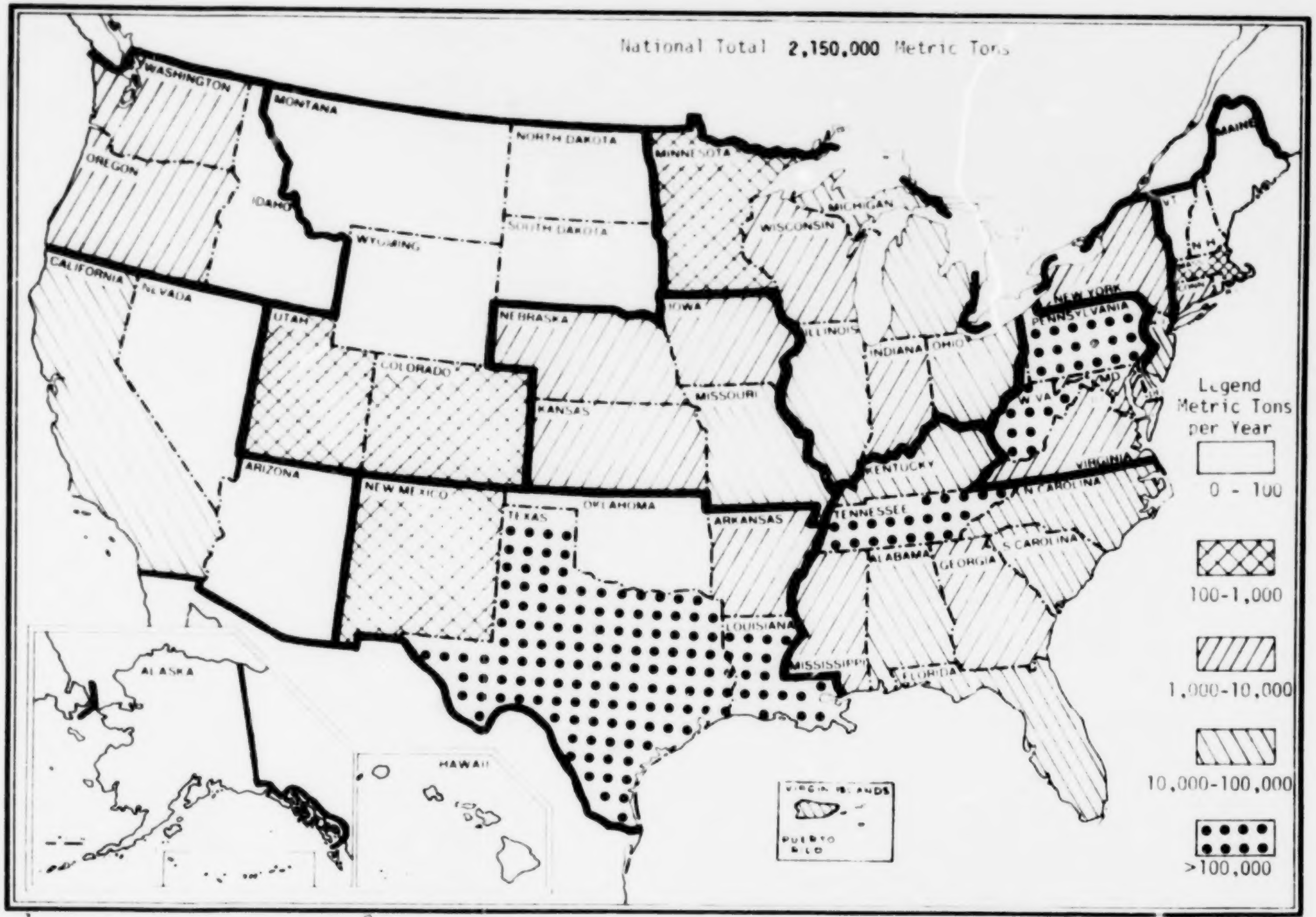
**Based on consideration of the solubility, dispersibility, physical form and concentration of all components rated as hazardous by the methods shown in Figure A-2.

Texas and Louisiana, the leaders in production, also led the states in the dry basis tonnage of estimated total process discharge to land disposal of hazardous waste streams in 1973 with 904,000 and 267,000 metric tons, respectively. Figure 2-1 presents a graphical interpretation of the distribution by state of the dry weight of hazardous process waste streams to land disposal.

The estimated total quantity of hazardous components contained in the process waste streams discharged to land disposal in the United States during 1973 was 840,000 metric tons — approximately 38 percent of the dry weight of the three industries' land-destined waste streams. Texas and Louisiana, with their high concentrations of organic chemical industry plant sites, are the national leaders.

Components classified as "highly dangerous" in this study constituted about 30 percent by weight of the hazardous components sent to land disposal in 1973. Texas and Louisiana accounted for slightly over half of this national total; other states with between 10,000 and 100,000 metric tons of "highly dangerous" components, were New Jersey, Pennsylvania, West Virginia, Tennessee, and Alabama.

The industrial organic chemicals industry (SIC 2869) hazardous process waste streams, with just under 1.5 million metric tons discharged to land, constitute approximately two-thirds of the national total from the five 4-digit SIC categories covered in this study (Table 2-2). For each kg of product, 0.023 kg of hazardous process waste streams were sent to land disposal by this major industry in 1973. The cyclic crudes and intermediates industry, at 500,000 metric tons, had a slightly higher hazardous waste generation factor — 0.027 kg per kg of product. Because of the high ecological hazard associated with discharge to water of their process wastes, the pesticides industries use land-based disposal processes for a high proportion of their hazardous wastes (158,000 metric tons in 1973), and the hazardous waste stream discharge to land factor is high — 0.088 kg per kg of product. Waste explosives for which land-based treatment and disposal practices are used totaled 21,000 metric tons in 1973; the waste discharge factor was low — 0.013 kg per kg of product. The gum and wood chemicals


National Total 2,150,000 Metric Tons
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S CAROLINA
N CAROLINA
VIRGINIA
W VA
MD
PENNSYLVANIA
NEW YORK
VT
N H
MAINE
ALASKA
HAWAII
VIRGIN ISLANDS
PUERTO RICO
Legend
Metric Tons
per Year
0 - 100
100-1,000
1,000-10,000
10,000-100,000
>100,000

[1] Estimated, dry basis

[2] Process Waste Streams containing one or more components classified as "Moderately Dangerous" or "Highly Dangerous" in this study.

Figure 2-1. Total Process Discharge to Land Disposal[1], Hazardous Waste Streams, Metric Tons for CY 1973 [2] for the Organic Chemicals, Pesticides and Explosives Industries

Table 2-2. Total Process Discharge to Land Disposal[1], Hazardous Waste Streams[2], Metric Tons for CY 1973, for the Organic Chemicals, Pesticides and Explosives Industries

		Organic Chemicals[3]			Pesticides	Explosives	
EPA Region	State	SIC 2861	SIC 2865	SIC 2869[3]	SIC 2879 & SIC 28694	SIC 2892	Total
4	Alabama	3542	13048	544	35241	99	52000
10	Alaska					6	6
9	Arizona				11	91	100
6	Arkansas				3560	10	3600
9	California		1795	7930	17303	323	27000
8	Colorado		14		882	18	910
1	Connecticut			815	864	15	1700
3	Delaware		22200		11	0.2	22000
3	District of Columbia						
4	Florida	8652		17953	367	44	27000
4	Georgia	2698	100	5931	602	20	9400
9	Hawaii				11	2	13
10	Idaho				11	8	19
5	Illinois		9676	1797	5592	1205	18000
5	Indiana		183	336	245	761	1500
7	Iowa				4335	297	4700
7	Kansas		1295	179	1557	902	3900
4	Kentucky		14	94311	11	180	95000
6	Louisiana	620	83413	159010	22894	1150	267000
1	Maine					3	3
3	Maryland		993		321	11	1300
1	Massachusetts		111		66	7	180
5	Michigan		17122	2940	7569	29	28000
5	Minnesota		46		130	54	230
4	Mississippi		1288	197	7025	3	8500
7	Missouri		2749	129	7183	377	10400
8	Montana				22	6	28
7	Nebraska				33	1058	1100
9	Nevada				22	13	45
1	New Hampshire				11	3	14
2	New Jersey		38928	3970	13934	4	54000
6	New Mexico					126	130
2	New York		953	4587	1337	19	6900
4	North Carolina		28190		240	18	28000
8	North Dakota					0.4	0.4
5	Ohio		2007	6810	1874	82	11000
6	Oklahoma				33	18	51
10	Oregon		46		1579	11	1600
3	Pennsylvania		23461	85070	572	156	109000
2	Puerto Rico		7349	8719			16000
1	Rhode Island		30	5		0.6	36
4	South Carolina		22349		245	3	23000
8	South Dakota					1	
4	Tennessee		29682	174512	6531	8528	219000
6	Texas		180077	708020	14851	553	904000
8	Utah		228		11	589	830
1	Vermont						
3	Virginia		3641		62	3508	7200
10	Washington				2537	12	2500
3	West Virginia		9157	172735	11	86	182000
5	Wisconsin				622	658	1300
8	Wyoming					6	6
NATIONAL TOTALS		15,512	503,106	1,456,738	158,000	21,123	2,150,000
		Gum and Wood Chemicals	Cyclic Crudes & Intermediates	Industrial Org., Chemicals NEC	Prep'ns, Formul'ns & Tech. Organic Pest Control	Private[4] & GOCO[5] Plants	

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[1] Estimated, dry basis.

[2] Defined as process waste streams containing one or more components classified as "moderately dangerous" or "highly dangerous" in this study.

[3] Excluding SIC 28694, technical organic pest control chemicals (covered under "Pesticides Industries").

[4] Includes waste explosives only for the privately owned and operated explosives industry plants.

[5] GOCO - Government Owned, Contractor Operated.

industry, with under 16,000 metric tons of hazardous process waste to land, is the lowest major industry in both production volume and hazardous waste discharge.

The impact projected for the Federal Water Pollution Control Act Ammendments is shown by the sharp increase in the estimate for discharge to land disposal in 1977 for hazardous waste streams — a jump to 3.5 million metric tons. The projection includes an increase of 10 percent in production from the 1973 level, with the exception of the GOCO portion of the explosives industry, which actually decreases slightly, and the assumption that industry plans called for the implmentation by 1977 of land-based procedures to handle pollutants whose discharge to water and air would no longer be permitted in 1983. Based on this assumption, 950,000 metric tons of hazardous waste streams formerly discharged to water and air will be handled by land-based treatment and disposal techniques in 1977. Table 2-3 shows the projections by state and major industry for 1977. The proportion of the total national hazardous waste stream discharge due to the industrial organic chemicals industry (SIC 2869) increases to 72 percent; that due to the cyclic crudes and intermediates industry drops slightly to 21 percent.

The respective hazardous waste generation factors are both approximately 0.036 kg per kg of product. The hazardous waste generation factor for the pesticides industries increases to about 0.1 kg per kg of product. The total quantity of hazardous waste discharged by the explosives industry is projected to remain relatively constant. The increase in hazardous waste tonnage projected for the gum and wood chemicals industry in 1977 is due solely to the projected increase in production.

The data presented in Table 2-4 are based upon an increase in production for 1983 versus 1977 of slightly over 10 percent for all industries other than the GOCO portion of the explosives industry. The projected total quantity of hazardous wastes to land for the United States in 1983 is 3.8 million metric tons; waste generation factors and relative proportions remain the same, except for the explosives industry's fraction, which decreases.

Table 2-3. Total Process Discharge to Land Disposal[1], Hazardous Waste Streams[2], Metric Tons for CY 1977 for the Organic Chemicals, Pesticides and Explosives Industries

EPA Region	State	Organic Chemicals [3]			Pesticides	Explosives	
		SIC 2861	SIC 2865	SIC 2869 [3]	SIC 2879/28694	SIC 2892	Total
4	Alabama	3897	27877	1595	42765	109	76000
10	Alaska			77		7	84
9	Arizona					100	100
6	Arkansas			1454	3853	11	5300
9	California		6515	41367	18688	142	67000
8	Colorado		32		1616	19	1700
1	Connecticut		210	925	1344	16	2500
3	Delaware		25278	1888	12	0.3	27000
3	District of Columbia						
4	Florida	9518		21484	423	48	31000
4	Georgia	2967	110	9958	668	22	14000
9	Hawaii				12	2	14
10	Idaho				12	9	21
5	Illinois		19513	28539	6169	1211	55000
5	Indiana		546	6278	272	767	7900
7	Iowa			1495	6310	299	8100
7	Kansas		2864	836	1712	902	6300
4	Kentucky		677	126412	12	198	127000
6	Louisiana	683	97532	343026	26217	1150	469000
1	Maine					3	3
3	Maryland		2370	7	434	12	2800
1	Massachusetts		118	1690	73	7	1900
5	Michigan		22174	4521	8684	32	35000
5	Minnesota		51		219	59	350
4	Mississippi		2251	1355	11419	1	15000
7	Missouri		3046	1866	9430	181	15000
8	Montana			447	28	6	480
7	Nebraska				36	1058	1100
9	Nevada		335		29	14	370
1	New Hampshire			129	12	3	140
2	New Jersey		64691	20194	16462	5	100000
6	New Mexico					129	130
2	New York		370	9206	3123	21	13000
4	North Carolina		34498	4935	[illegible]	20	40000
8	North Dakota					0.4	0.4
5	Ohio		3093	34073	2827	90	40000
6	Oklahoma			189	36	20	250
10	Oregon		51	5560	1737	12	7400
3	Pennsylvania		43308	106550	709	121	150000
2	Puerto Rico		20612	92589		-	113000
1	Rhode Island		32	598		0.6	630
4	South Carolina		24585	1414	330	3	26000
8	South Dakota					1	1
4	Tennessee		32803	218159	9608	8533	269000
6	Texas		222767	1236372	21027	535	1481000
8	Utah		341		12	523	880
1	Vermont						
3	Virginia		5833	353	74	3514	9800
10	Washington		4904	993	2941	13	8900
3	West Virginia		18137	209021	12	94	228000
5	Wisconsin		825	671	717	659	2900
8	Wyoming					6	6
NATIONAL TOTALS		16702	741494	2521751	196979	20950	3500000
		Gum and Wood Chemicals	Cyclic Crudes & Intermediates	Industrial Org. Chems. NEC.	Prepns, Formulns. & Tech Pesticides	Private [4,5] & GOCO Plants	

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[1] Estimated, dry basis.

[2] Defined as process waste streams containing one or more components classified as "moderately dangerous" or "highly dangerous" in this study.

[3] Excluding SIC 28694, technical organic pest control chemicals (covered under "Pesticide" Industries").

[4] Includes waste explosives only for the privately owned and operated explosives industry plants.

[5] GOCO = Government Owned, Contractor Operated.

Table 2-4. Total Process Discharge to Land Disposal[1], Hazardous Waste Streams[2], Metric Tons for CY 1983, for the Organic Chemicals, Pesticides and Explosives Industries

EPA Region	State	Organic Chemicals			Pesticides	Explosives	
		SIC 2861	SIC 2865	SIC 2869[3]	SIC 2879/28694	SIC 2892	Total
4	Alabama	4308	30816	1763	42369	120	[illegible]
10	Alaska			85		8	93
9	Arizona					110	110
6	Arkansas			1608	4259	12	5900
9	California		7201	45729	20658	330	74000
8	Colorado		36		1736	22	1800
1	Connecticut		232	1023	1488	18	2800
3	Delaware		27943	2087	13	0.2	30000
3	District of Columbia						
4	Florida	10521		23749	468	53	35000
4	Georgia	3279	121	11088	739	24	15000
9	Hawaii				13	2	15
10	Idaho				13	10	23
5	Illinois		21570	31549	6820	1218	61000
5	Indiana		603	6940	300	771	8600
7	Iowa			1653	7842	102	9600
7	Kansas		3166	324	1893	901	6300
4	Kentucky		747	139747	13	219	141000
6	Louisiana	755	107817	379700	28983	1151	518000
1	Maine					4	4
3	Maryland		2620	8	479	11	3100
1	Massachusetts		175	1068	13	[illegible]	1300
5	Michigan		28521	5406	9590	36	43000
5	Minnesota		56		265	88	400
4	Mississippi		3041	1497	11540	1	16000
7	Missouri		1367	2063	10478	[illegible]	14000
8	Montana			494	27	7	530
7	Nebraska				40	1068	1100
9	Nevada		170		27	14	211
1	New Hampshire			142	13	3	160
2	New Jersey		71983	22345	12994	5	111000
6	New Mexico					111	110
2	New York		2166	10193	1793	83	14000
4	North Carolina		38117	5456	135	32	44000
8	North Dakota					0.5	0.5
5	Ohio		3415	37659	3125	99	44000
6	Oklahoma			209	40	22	270
10	Oregon		56	6147	1920	13	8100
3	Pennsylvania		41962	116680	714	199	160000
[illegible]	Puerto Rico		22786	102364			125000
1	Rhode Island		34	661		0.7	700
4	South Carolina		27172	1563	364	4	29000
8	South Dakota					1	1
4	Tennessee		36260	241166	10620	5539	292000
6	Texas		246259	1366292	23241	358	1637000
8	Utah		247	4	13	168	430
1	Vermont					3	3
3	Virginia		6389	390	83	3521	10400
10	Washington		5041	1097	3251	14	9400
3	West Virginia		20046	231063	13	106	251000
5	Wisconsin		912	741	793	661	3100
8	Wyoming					7	7
NATIONAL TOTALS		18864	762440	2903035	217,710	21026	3900000
		Gum and Wood Chemicals	Cyclic Crudes & Intermediates	Industrial Org., Chemicals, NEC	Prep'ns, Formul'ns & Tech Pesticides	Private[4,5] & GOCO Plants	

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[1] Estimated, dry basis.
[2] Defined as process waste streams containing one or more components classified as "moderately dangerous" or "highly dangerous" in this study.
[3] Excluding SIC 28694, technical organic pest control chemicals (covered under "Pesticides Industries").
[4] Includes waste explosives only for the privately owned and operated explosives industry plants.
[5] GOCO = Government Owned, Contractor Operated.

2.3 TREATMENT AND DISPOSAL TECHNOLOGY

Three treatment and disposal technology levels are identified in this study. Level I technology represents the practice currently employed by typical facilities — broad, average, present treatment and disposal practice. Level II is the best technology currently in commercial use in at least one location for the same or a similar application — "best" here referring to the adequacy of the process from an environmental and health standpoint. Level III is the technology necessary to provide adequate environmental protection, and may include pilot or bench scale processes. Level I, II, and III technology may be identical in those cases where the broad, average, present treatment is both the best technology currently in use and is environmentally adequate.

Company and Government agency supplied information, covering treatment and disposal technology employed at 52 major plant sites, was obtained by plant visits or through other direct contact, for use in this study. For the organic chemicals and pesticides industries, the data embraced the technology for disposal of just under 200 waste streams. Data were received from the U.S. Army Armament Command on waste management activities at all of the Army ammunition plants. In addition site visits were conducted at three of the four active basic high explosives manufacturing plant sites and information was furnished on treatment and disposal development projects.

The sample of the organic chemicals industry, for which information on treatment and disposal technology was obtained by direct contact, was selected on the basis of the types and quantities of products manufactured, the hazards estimated for the process wastes generated, the geographical locations of the plants, and the willingness of the plant managements to cooperate in this study. The data for this sample of the organic chemicals industry (organic chemical plants produced the bulk of the hazardous waste discharges included in this study) indicate that uncontrolled on-site incineration was the Level I technology used on almost one-half (48 percent, or 67,000 metric tons) of the dry weight of the sample's wastes. Controlled on-site incineration (considered to be Level II and II technology) was used on just under 22 percent, on-site landfill 15 percent, recovery on about 8 percent, contract disposal on slightly over 5 percent, and deep well injection on approximately 2 percent of the dry weight of the sample's wastes.

In numerical frequency of use, on-site landfill and incineration were used on approximately 32 and 33 percent, respectively, of the sample's hazardous waste streams. Contractor disposal was used on 9 percent, resource recovery on 12 percent, biological treatment/lagooning on 7.5 percent, deep well injection on under 6 percent, and landfarming on 1 percent of the sample's hazardous waste streams.

"Uncontrolled incineration" is defined for this study as the disposal of wastes by combustion in facilities which lack treatment processes adequate for the protection of the environment from the combustion products. "Controlled incineration" is defined as the disposal of wastes by combustion using the technology necessary to provide adequate environmental protection. The treatment processes and technology currently used in controlled incineration for protection of the environment from the combustion wastes include (but are not limited to):

> Properly designed and operated afterburners and secondary combusion systems to abate NOx emissions; settling chambers, impingement and cyclone separators, bag filters, electrostatic precipitators, packed towers, and spray chamber, venturi and cyclone scrubbers for the removal of particulate and gaseous contaminants from the incinerator vent gases; and evaporators, ponds, lagoons, land farms and chemical landfill for ash, collected particulate material, and scrubber liquid wastes not suitable for recovery or reuse.

To place this sample of the organic chemicals industry in perspective, the number of waste streams injected into deep wells in the sample was ten, versus a national total of 280 deep wells used for disposal of chemical process wastes in 1973.(1) The sample also has a relatively high percentage of major companies. The 7 percent by weight of the estimated organic chemicals industry total hazardous waste discharge covered in the sample makes the survey of treatment and disposal technology statistically significant. The geographical dispersion is considered sufficient to avoid bias. The proportion of the wastes handled by contract disposal for the industry as a whole is believed to be higher than that reported for the sample.

The data for the treatment and disposal methods used for the 25 waste streams in the pesticides industries sample indicate that landfill (on-site and contractor) has the highest usage rate, 40 percent, divided into 28 percent on-site and 12 percent contract disposal. The next three prevalent practices are incineration (16 percent), storage in drums or open piles* (13 percent) and resource recovery (8 percent).

For the safety-oriented military explosives industry, the single prevalent method of disposal of waste explosives is open burning. Controlled incineration of waste explosives has been tested successfully in pilot plant and prototype operations. The other major land-destined waste from the GOCO explosives industry — red water from TNT manufacture — is incinerated in rotary kilns; the ash from incineration is stored uncovered on-site.

The majority of the privately owned and operated sector of the explosives industry uses open burning. Chemical detoxification, contract disposal, sale of scrap for reclamation, deep-well injection and spray irrigation are other techniques employed to a lesser extent.

It is believed that many of the applications of treatment and disposal techniques described above represent real or potential hazards to the environment. The following waste management technologies, as applied to the hazardous waste streams of the sample, are considered either inadequate or of dubious adequacy for environmental protection:

1. Uncontrolled incineration. This technique was used in 1973 on almost one-half of the hazardous wastes of the organic chemicals and pesticides industries plants in the sample, and on all of the waste explosives of the GOCO plants. It thus represents Level I technology for the three industries. It afforded no protection against discharge to the atmosphere of such noxious pollutants as nitrogen oxides, sulfur oxides, carbon monoxide, hydrogen halides, residual chlorinated organics, and polynuclear aromatic hydrocarbons.

2. Landfill on sites insufficiently characterized and therefore potentially unsuitable for the disposal of hazardous wastes. Two-thirds of the hazardous wastes disposed of by landfill at the organic chemicals and pesticides plants in the sample were disposed at sites for which there was inadequate knowledge of subsurface geology, ground water course locations, leaching characteristics, and run-off and drainage protection requirements. The protection afforded the environment against contamination by water-soluble or dispersible toxic materials was therefore doubtful or insufficent.

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*Long-term storage was used in 1973 by some companies as an ultimate disposal technique.

3. Deep well injection of hazardous process wastes. This method for disposal was used on 2 percent by weight of the sample plants' hazardous process wastes, with no effective pretreatment at any plant prior to dilution and injection. There was little or no knowledge of the capabilities of the injection strata to serve as adequate permanent liquid storage reservoirs or to protect developed and undeveloped mineral resources, including ground water. There was a similar lack of knowledge on the migration and chemical change characteristics of the hazardous materials injected.

One waste stream from each of fifteen hypothetical "typical" plants (selected from the twenty-six which were listed in Section 2.2) was chosen for analysis of waste treatment and disposal technology typical of the organic chemicals and technical pesticides industries. Selection was on the basis of product significance and the hazardous character of the wastes. The plants chosen produce perchloroethylene, nitrobenzene, chloromethane solvents, epichlorohydrin, toluene diisocyanate, vinyl chloride monomer, methyl methacrylate monomer, acrylonitrile, maleic anhydride, lead alkyls, aldrin, atrazine, trifluralin, parathion, and malathion.

Each waste stream was selected to give a composite picture of the treatment and disposal technologies employed on land-destined waste streams. The Level I treatment and disposal technologies selected for the composite picture were heavily dependent upon the techniques described above. Uncontrolled incineration was the disposal method which represented the broad average of processes used on the hazardous waste at typical vinyl chloride monomer, methyl methacrylate monomer, acrylonitrile, lead alkyl and parathion plants. Landfill on sites which were not necessarily environmentally acceptable for hazardous waste disposal was the Level I technology for the typical chloromethane solvents, toluene diisocyanate, and maleic anhydride production facilities. Level I disposal technology for the hazardous waste streams of the typical perchloroethylene plant and of the single atrazine producer was deep well disposal. The Level I technologies for nitrobenzene, epichlorohydrin, aldrin, trifluralin and malathion were on-site landfill, on-site storage, lined pond, storage in rubber-lined drums and detoxification with NaOH and burial with NaOH in approved landfill, respectively.

The Level II and III treatment technology was controlled incineration for eight of the fifteen waste streams. "Controlled incineration, with lead recovery" was the Level II and Level III technology for one additional waste stream. The use of landfills suitable for the disposal of hazardous wastes ("Secured landfills") was Level II technology for three waste streams, and Level III technology for two waste streams.

2.4 TREATMENT AND DISPOSAL COSTS

Treatment and disposal costs estimated for Level I technology for the selected examples of land-destined hazardous wastes discharged by the organic chemicals and pesticides industries range from $0.24 to $137.27 per metric ton* of product in December 1973 dollars. The Level I treatment and disposal technology costs per metric ton of hazardous waste (wet basis) were estimated to vary between $0.57 and $323.33. The weighted average** of costs estimated for Levels I, II and III disposal technology for the selected hazardous waste streams from the typical organic chemicals and pesticides plants were as follows:

Level I	$13.36 per metric ton of waste (wet basis)
Level II	$30.56 per metric ton of waste (wet basis)
Level III	$30.69 per metric ton of waste (wet basis)

Expressed in terms of cost per metric ton of waste (dry basis), these weighted averages are for Level I, $48.32; for Level II, $110.54; and for Level III, $111.02. It should be noted that the Level II treatment and disposal technology was the same as Level III for thirteen of the fifteen hazardous waste streams considered and that this is primarily responsible for the small difference between the estimated costs for these two levels of technology. The costs of disposal for the 15 commodities, calculated as percent of 1973 sales values from the U.S. International Trade Commission preliminary reports for 1973 on organic chemicals,(3) had a weighted average of 0.9 percent for Level I disposal technology, and 2.2 percent for Level II and III technologies.

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*In other sections of this report, "metric ton" and "tonne" have been used interchangeable.

**Weighted in accordance with the quantity of wastes estimated as national total for each of the 15 commodities.

Current open burning techniques (Level I technology) used for military explosive waste disposal range in cost from $2.90 per metric ton of waste to $641.30 per metric ton of waste.* Data from the preliminary economic evaluation of pilot plant studies of controlled incineration (Level II technology) were not available for this report.

The costs of treatment and disposal for the 2.2 million metric tons (dry basis) total land-destined wastes generated in 1973 by the organic chemicals, pesticides and explosives industries is estimated at approximately $106,000,000. The basis used for calculation of this figure was the weighted average estimate of $48.32 per metric ton of waste (dry basis) for the application of Level I disposal technology to the hazardous waste streams of the 15 typical organic chemical and pesticide plants. The value of organic chemical, pesticide and explosive industry sales in 1973 was estimated, based on extrapolation of the data of the U.S. International Trade Commission preliminary reports for 1973 on organic chemicals,(3) as about $21,740,000,000. The estimated cost of Level I treatment and disposal technology ($106,000,000) for these three industries thus amounts to approximately 0.5 percent of the estimated total sales.

The costs for the application of Level II and Level III treatment and disposal technologies to the total land-destined wastes generated in 1973 by the three industries are estimated at approximately $242,000,000 and $243,000,000,respectively. The bases used for the calculation of these figures were the weighted average estimates of $110.54 per metric ton of waste (dry basis) for the application of Level II technology, and $111.02 per metric ton of waste (dry basis) for the application of Level III technology for the fifteen commodities considered. It should be noted that, based on these cost data which are for the fifteen commodities considered, there is little difference between the estimated costs for the application of Level II and Level III technologies and that the estimated cost of $242,000,000 - $243,000,000 amounts to approximately 1.1 percent of the total 1973 sales for the three industries.

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*This very high cost for disposal is due to the extremely hazardous character of some of the explosive wastes, and the special precautions required in waste handling, transportation, and disposal.

3. METHODOLOGY

The methodology employed for deriving the quantitative figures presented in this study may be summarized as follows:

- Obtain data from the open literature and industry, government and trade association sources to the level of maximum detail available for this study.
- Make qualified estimates of all necessary statistics at the level of maximum detail where sufficient "hard" data were obtained to justify estimation.
- Categorize, classify, and assign hazard ratings to all waste components.
- Summarize the estimates statistically for each state, by product first, if possible, and then by five digit Standard Industrial Classification product group.
- Evaluate the statistical summaries, and develop the descriptions to characterize the industries, their hazardous waste streams, and the land treatment and disposal practices employed or available, and the costs of these practices.

The level of detail of the data available for this study varied considerably. Restrictions on data accessibility depended upon the industry to which the request was made, and upon the information requested. The majority of the organic chemical companies contacted considered plant and company-wide production rate data on individual products to be proprietary information. They did, however, furnish lists of the names of the chemicals manufactured at each plant site. The national total production for each synthetic organic chemical was available from Government sources(3,4). In consequence, as discussed more completely in Appendix A under "Data Acquisition," although "hard" individual plant production rate data on organic chemicals was not accessible for use in this study, enough information was available to justify estimation. Estimates were made of the 1973 production rate of each synthetic organic chemical* produced by each plant by prorating the national total production. In contrast, for the pesticides preparations and formulations industry (SIC 2879), the available literature(5) and one other information source(6) gave TRW access only to data on the value of total industry products shipped, nationally and by census region, and on the number of "establishments" in each state. The estimates made for this industry (SIC 2879) were at the state level.

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*Restricted to organic chemicals which met the criteria stipulated in Appendix A under "Data Collation and Analysis."

Ground rules covering the limits of this study were developed to avoid interface problems and double accounting for production and hazardous waste data. These were:

1. Organic chemicals, which were manufactured as intermediates to be used in other industries (e.g., plastics, drugs, and paints), were considered as products of the organic chemicals industry if their use was not wholly captive to the plant site, i.e., if portions of the production were transported to other plant sites for the further processing necessary, or sold on the open market as intermediates/merchant chemicals.

2. Those hydrocarbons which were direct products of oil company refinery operations (e.g., methane, ethylene, propylene, and benzene) were not considered to be products of the organic chemicals industry. Those chemicals, which were the products of petrochemical operations (e.g., isopropanol, acetone, and isophthalic acid), were considered to be products of the organic chemicals industry. These categorizations followed the practice employed in oil company reporting to the United States International Trade Commission (formerly the U.S. Tariff Commission).

3. Crude coal tar was considered to be a product of the ferrous metals industry, and a raw material (rather than a product) of the organic chemicals industry. Refined coal tar, pitch, and coal tar-derived chemicals were considered to be products of the organic chemicals industry.

Companies and agencies which supplied information for use in this study are listed in Table A-1 in Appendix A. The details of the approach to data acquisition, data collation and analysis, hazardous waste identification and estimation, treatment and disposal technology evaluation and cost analysis are presented in Appendix A.

Criteria were developed to enable proper identification and estimation of hazardous wastes, and to assure consistency between the definitions employed in the separate multi-industry studies of industrial hazardous waste practices being conducted for the EPA. The criteria divided waste streams into two major categories on the basis of the characteristics of their components — "hazardous wastes" and "other wastes". "Hazardous wastes" were separated further into two classes — "moderately dangerous" and "highly dangerous".

The major bases used to assess the waste streams were:

1. Potential to cause human death, injury, illness, or harm to wildlife/beneficial biota.
2. Possible paths for harmful entry to the environment, throughout the entire cycle of waste management.

Under the considerations noted above, "hazardous wastes" was the designation for all waste streams which contained one or more components which were:

1. Classified as "moderately dangerous" or "highly dangerous" based on the rating table shown in Table 3-1. The rating system shown in the table was developed by TRW based on published literature data (in particular, Reference 54) and in conjunction with discussions with other EPA contractors concurrently involved in similar assessment studies for other industries.
2. Any of the following specific substances or types of substances: Asbestos, arsenic, beryllium, cadmium, chromium,[1] copper, cyanides,[2] lead, mercury, halogenated hydrocarbons, pesticides, selenium and zinc.
3. Assessed as explosive [3], carcinogenic, oncogenic (tumor forming), teratogenic, mutagenic, subject to bioaccumulation to toxic level[4], strongly corrosive or a strong sensitizer.

In addition, where the actual physical characteristics of a waste were such as to endanger, actually or potentially, life or limb, the waste could be classified as a "hazardous waste," e.g., wastes discharged directly to the environment at high temperature or high pressure could be classified as "hazardous wastes".

The term "other wastes" was applied to all waste streams not classified as "hazardous wastes".

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[1] Hexavalent chromium compounds only

[2] Except ferrocyanide compounds

[3] As defined in Appendix A

[4] All bioconcentratable materials were raised to the next higher hazard classification

Table 3-1. Hazard Categories and Classes — Rating Table*

Rating	Hazard Type													
	Fire and Explosion		Health Effects								Aquatic	Reactivity		
Hazard Category (Class)	Flash Point Closed Cup, °F	Explosiveness	Skin and Eyes LD50, derm mg/kg	Eyes, Throat, Lungs Irritation	Skin Irritation	Acute Inhalation LC_{50} ppm	Repeated Inhalation OSHA std. ppm	Prolonged Inhalation TLV ppm	Mammal Toxicity LD_{50}, oral mg/kg	Mammal Toxicity LD_{50}, derm mg/kg	Aquatic Toxicity TLm mg/l	Water	Chemical	Self-Reaction
Other wastes — OW	Not combustible	Not capable of deflagration or explosion	[Practically harmless]	Non-volatile, non-irritant	Practically harmless	[No	Likelihood of	Injury]	>500	>2000	>100	No hazardous reaction with water	Chemically unreactive	No appreciable self-reaction
Hazardous wastes														
Moderately Dangerous — MD	<100 (& boil >100°F)	Capable of very rapid burning	[Corrosive to eyes]	Slight smarting at high concentrations	Smarting & redness if contact continued	[Dizziness in atmosphere saturated at 122°F (>200)]	<1000 (& >10)	<500 (& >10)	<500 (& >50)	<2000 (& >200)	<100 (& >10)	Relatively mild chemical and physical reaction	May react with highly reactive chemicals	May polymerize with low heat evolution
Highly Dangerous — HD	<100 (& boil <100°F)	Capable of generating a sudden rapid rise in pressure on initiation	<200	Severe irritants, intolerable at low concentration permanent injury possible	Severe irritants, cause pain and 2nd degree burns in a few minutes	<200	<10	<10	<50	<200	<10	Vigorous reaction with H_2O (similar to Oleum)	Highly reactive with all chemicals	Hazardous self-reaction—stabilizer or inhibitor required for storage/shipment

Note: *The rating system was developed by TRW based on published literature data (in particular, Reference 54) and in conjunction with discussions with other EPA contractors concurrently involved in similar assessment studies for other industries.

All bioconcentratable materials were raised to the next higher Hazard Classification.

All suspected carcinogens, explosives, oncogens, teratogens, mutagens, components subject to bioaccumulation to toxic levels, strong corrosives and strong sensitizers were rated as HD.

(a) 24-hour contact

4. INDUSTRY CHARACTERIZATION

4.1 GENERAL

The organic chemicals, pesticides and explosives industries have been characterized statistically, to the maximum extent consistent with the best sources of non-proprietary data available, in the summaries which follow. The most complete of the summaries - those for organic chemicals (including technical organic pest control chemicals) and government-owned-contractor-operated (GOCO) explosives manufacture - describe the industry product groups in terms of:

- The number and location of manufacturing plant sites
- The distribution of plant sizes, in terms of production capacity at each plant site, for the commodities in the individual product groups
- The distribution of processes used
- The distribution of actual production for each product group.

Where the data were more limited (i.e., the pesticides formulations and non-defense explosives subcategories of the industries) the summaries were limited to the number and location of manufacturing plant sites, and the production total for each state.

The term "plant site" has been used herein to identify each facility where one or more of the commodities (organic chemicals, pesticides or explosives) covered in this study are manufactured. A given plant site, by this definition, may contain any number of processes (in some cases, 30 or more) each producing a different commodity.

This study covers all sources* for commodities meeting the criteria cited in Appendix A, in the following major industry classifications:(7)

2861 Gum and wood chemicals (organic chemicals industry)
2865 Cyclic crudes and intermediates (organic chemicals industry)

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*The number of plant sites covered in this study is larger than that based on Census of Manufactures figures, since the Census is concerned only with those establishments whose primary products are organic chemicals, pesticides and explosives.

2869 Industrial organic chemicals, NEC* (organic chemicals industry)

2879 Agricultural chemicals, NEC* (pesticides preparations and formulations)

2892 Explosives

The five-digit SIC product groups (each of which may cover as many as a hundred individual commodities) which more thoroughly categorize the industries are as follows:(3,7)

Major Industry SIC Number	Product Group SIC Number	Description
2861		Gum and wood chemicals industry
	28611	Softwood distillation products
	28612	Other gum and wood chemicals (hardwood distillation products)
	28610	Gum and wood chemicals, not specified by kind
2865		Cyclic crudes and intermediates industry
	28651	Cyclic intermediates
	28652	Synthetic organic dyes
	28653	Synthetic organic pigments, lakes, toners
	28655	Cyclic (coal tar) crudes
	28650	Cyclic crudes and intermediates, not specified by kind
2869		Industrial organic chemicals, NEC, industry
	28691	Miscellaneous cyclic (coal tar) chemical products
	28692	Miscellaneous acylic chemicals and chemical products

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*Not elsewhere classified

Major Industry SIC Number	Product Group SIC Number	Description
	28693	Synthetic organic chemicals, NEC (flavor and perfume materials, rubber processing chemicals, plasticizers, etc.)
	28694	Pesticides and other synthetic organic agricultural chemicals (except preparations)
	28695	Ethyl alcohol and other industrial organic chemicals, not elsewhere classified
2879		Agricultural chemicals, NEC, industry
	28791	Insecticidal preparations (formulations) primarily for agricultural, garden and health service use
	28792	Herbicidal preparations (formulations) primarily for agricultural, garden and health service use
	28793	Agricultural chemicals, NEC
	28794	Household insecticides and repellants, including industrial exterminants
	28790	Agricultural chemicals, not specified by kind
2892		Explosives industry
	28921	Explosives, propellants and blasting accessories (except GOCO plants)
	28922	Explosives, propellants and blasting accessories (GOCO plants)

4.2 ORGANIC CHEMICALS INDUSTRY

The only general characterization of the organic chemicals industry which may be used safely is one which cites the great number and wide diversity of commodities produced, the enormous number and complexity of production processes, the wide variation in capital and labor intensity, the extreme sophistication and frequency of advances and changes in technology, and the fiercely competitive character of this industry. There were more than 700 organic chemicals manufactured in 1973 whose individual annual interplant shipments or merchant sales in the United States were in excess of 453 metric tons (1 million pounds).(3,4) The total value added by manufacture in 1972 was over $6 billion, and the total value of product shipped was $11.4 billion.(8,9,10) The number of plants (regardless of Bureau of Census classification as to industry)*(7) which produced and shipped these organic chemicals was 1204.

The organic chemicals industry (SIC 286) is subdivided into three major industries: SIC 2861, gum and wood chemicals; SIC 2865, cyclic crudes and intermediates; and SIC 2869, industrial organic chemicals, NEC.** Of these, the industrial organic chemicals industry is by far the largest (product shipped in excess of $9 billion) followed by the cyclic crudes and intermediates industry (shipments of $2 billion). The gum and wood chemicals industry is the smallest with $330 million in shipments.

The average number of total employees per establishment for the organic chemicals industry, based on the 1972 Census of Manufactures (Preliminary Report)(8,9,10) was 1654. The average number of production employees was 1062. Approximately 55 percent of the establishments reporting had 20 or more employees. The average number of employees was highest (just under 2,000) in SIC 2869, the industrial organic chemicals NEC product group. Value added by manufacture per plant was, similarly, highest for this product group by a significant factor ($9,900,000 versus $3,500,000 for the remainder of the organic chemicals industry). In 1972 small manufacturing firms (those with less than 10 employees) accounted for a weighted average of about 0.5 percent of the total value added by manufacture for the organic chemicals industry (SIC 286). The portion of value added by manufacture by small producers for each of the three major industries was: SIC 2861, gum and wood chemicals, 10 percent; SIC 2865, cyclic crudes and intermediates, 0.3 percent; and SIC 2869, industrial organic chemicals NEC, 0.2 percent.(8,9,10)

A statistical summary characterizing the organic chemicals industry is presented in Tables 4-1 through 4-5. The summary contains the following information:

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* See footnote on page 4-1.

**Not elsewhere classified.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification[*]

SIC	Chemical Products
28611	Charcoal briquettes
	Pine oil
	Pine tar compounds
	Rosin, wood
	Turpentine, wood
28612	Charcoal briquettes
	Dyewood extracts
	Methanol, natural
	Naval stores
	Rosin, tall oil
	Rosin, gum
	Tall oil, crude and distilled
	Tanning extracts
28651	Acetophenone
	Alkylates, branched
	Alkylates, linear
	4-Amino-diphenyl
	Aniline
	Anthraquinones, substituted
	Benzidine
	Benzoic acid
	Bisphenol A (para, para' -isopropylidenediphenol)
	Chlorobenzene, mono
	Chlorotoluene, alpha
	2-Chlorotoluene
	4-Chloro-1-nitrobenzene
	Cresols
	Cumene
	Cyclohexane
	Cyclohexanone
	Cyclohexylamine and derivatives
	o-Dichlorobenzine
	p-Dichlorobenzine
	3,3-Dichlorobenzidine, base and salts
	Dicyclopentadiene
	4-Dimethylaminoazobenzene
	2,4-(and 2,6-) Dinitrotoluene

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[*] The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28651	Diphenylamine
	Ethyl benzene
	Hydroquinone
	(Mono, Di, and Tri) Toluene isocyanates
	Isophthalic acid
	Melamine
	Moca (4,4 - Methylenebis (2-chloroaniline))
	Alpha-naphthylamine
	Beta-naphthylamine
	Nitroaniline
	Nitrobenzene
	4-Nitrodiphenyl
	Nonylphenol
	Phenol
	Phthalic anhydride
	2-Cu Phthalocyanate
	Pyridines
	Resorcinol
	Salicylic acid
	Styrene
	Terephthalic acid
	Toluene 2,4-diamine
	1,2,4-Trichlorobenzene
28652	Acid dyes
	Basic Dyes
	Direct dyes
	Disperse dyes
	Fluorescent brightening agents
	Solvent dyes
	Vat dyes
28653	Pigment blue toners
	Pigment green toners
	Pigment red toners
	Pigment yellow toners
28655	Benzene
	Creosote (oil)
	Cresylic acid
	Naphthalene

---

*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28655	Chlorodifluoromethane
	Pitch (coal tar)
	Tar (coal)
	Toluene
	Xylenes
28691	2-Acetylaminofluorene
	Benzoic acid, sodium salt
	Benzoyl peroxide
	Dimethyl terephthalate
	Dioxane (1,4-diethylene oxide)
	2,6-Di-tert-butyl-p-cresol
	Lithium compounds
	Methylstyrene, alpha
	Morpholine
	Naphthenic acid and salts
	Oil-soluble petroleum sulfonates; calcium salt
	Oil-soluble petroleum sulfonates; sodium salt
	Phenol salts
	Phosphorous compounds
	Pinene, alpha
	Pinene, beta
28692	Acetaldehyde
	Acetic acid
	Acetic acid salts; copper acetate; potassium; zinc
	Acetic anhydride
	Acetone
	Acetylene
	Acrylic acid and acrylates plus 2-ethyl-1-hexyl acrylate
	Acrylonitrile
	Adipic acid
	Alcohols; C_{10} or higher
	Alcohols; C_6 or lower
	Aluminum compounds
	Butadiene; 1-3
	Butanol-N
	Butanol-sec
	Butylamines; mono; di; tri
	n-Butyl acetate
	Butyl acrylate
	Butyraldehyde

---

*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28692	Caprolactam
	Carbon disulfide
	Carbon tetrachloride
	Cellulose acetate
	Cellulose ethers
	Chlorinated paraffins
	Chloroacetic acid, mono
	Chlorodifluoromethane
	Chloroform
	Citric acid
	Diacetone alcohol (4-hydroxy, 4-methyl, 2-pentanone)
	1,2-Dibromoethane, (ethylene dibromide)
	Dibutyl maleate
	Dichlorodifluoromethane
	1,2-Dichloropropane
	Diethylamine
	Diethylenetriamine
	Diethylene glycol
	Dipropylene glycol
	Dodecenylsuccinic anhydride
	Epichlorohydrin
	Ethanol (28695)
	Ethanolamines (mono; di; tri)
	Ethylene
	Ethylenediamine
	Ethyleneimine
	Ethylene dichloride
	Ethylene glycol
	Ethylene glycol diacetate
	Ethylene oxide
	2-Ethyl 1-hexanol
	Ethyl acetate
	Ethyl acrylate
	Ethyl chloride
	Ethyl ether
	Ethyl hexanediol
	2-Ethyl hexanoic acid and salts
	Fluorocarbons
	Formaldehyde
	Formic acid
	Formic acid, sodium salt (sodium formate)

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28692	Fumaric acid
	Furaldehyde-2
	Glutamates
	Glycol ethers
	Glycerin
	Hexamethylenetetramine
	Hexamethylenediammonium adipate
	Hexanediamine (1,6-hexamethylenediamine)
	Hexylene glycol (2-methyl-2,4-pentanediol)
	Hydrocarbons
	Isobutyl acetate
	Isobutyl alcohol
	Isoprene
	Isopropyl acetate
	Isopropyl alcohol
	Isopropyl ether
	Lactic acid
	Lead alkyls
	Lithium compounds, acyclic
	Maleic anhydride
	Mercaptans; sulfides (from petroleum)
	Methanol
	Methylamines
	Methylene chloride
	Methyl chloromethylether
	Methyl acetate
	Methyl chloride
	Methyl ethyl ketone
	Methyl isobutyl ketone
	Methyl methacrylate
	Nitriloacids and salts
	N-Nitrosodimethylamine
	Olefins, alpha
	Organo-tin compounds
	n-Paraffins
	Pentaerythritol
	Perchloroethylene
	Phosgene
	Phosphorodithioates (thiophosphates)
	Phosphorous acid esters
	Phosphorous compounds

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28692	Polyethylene glycols and polypropylene glycols
	Beta-propiolactone
	Propionic acid
	Propionic acid salts
	Propylamines
	Propylene
	Propylene glycol
	Propylene oxide
	Propyl acetate
	Propyl alcohol
	Sorbitol
	Stearic acid salts
	Tetraethylenepentamine
	Tetraethyllead
	1,1,1-Trichloroethane
	Trichloroethylene
	Trichlorofluoromethane
	Trichloromethane
	Triethylenetetramine
	Triethylene Glycol
	Vinyl bromide monomer
	Vinyl acetate monomer
	Vinyl chloride monomer
28693	Adipic acid esters
	Benzyl benzoate
	Dimethyl-3,7-trans-2;6-octadien-1-01 (geraniol)
	Dithiocarbamic acid derivatives
	Dodecyl mercaptans
	Epoxidized esters
	Isopropyl myristate
	Oleic acid esters
	Phenolic compounds
	Phosphite compounds
	Phosphoric acid esters
	Phthalic anhydride esters
	Saccharin
	Stearic acid esters
	Thiazole derivatives
	Thiurams
	Trimellitic acid esters

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28694	Acrolein
	Aldicarb
	Alachlor
	Aldrin
	Alpha-naphthylthiourea
	Amitrole
	Atrazine
	Bacillus thuringiensis
	Barban
	Benomyl
	Bis chloromethyl ether
	Binapacryl
	1,1-Bis(chlorophenyl)-2,2,2-trichloro-ethanol
	Bromacil
	2-(p-tert-butylphenoxy)cyclohexyl 2-propynyl sulfite
	N-Butyl-N-ethyl-alpha,alpha,alpha-trifluoro-2,6-dinitro-p-toluidine
	Cacodylic acid
	Captan
	Carbofuran
	2-Carbomethoxy-1-methylvinyl dimethyl phosphate, alpha isomer
	Carbaryl
	Carbophenothion
	Chloramben
	Chlorbromuron
	Chlordane
	2-chloroallyl diethyldithiocarbamate
	2-chloro-4,6-bis(isopropyl amino)-S-triazine
	2-chloro-N-isopropylacetanilide
	Chloroneb
	Chloroxuron
	Chlorpyrifos
	Copper naphthenate
	Crufomate (4-tert-butyl-2-chlorophenyl methyl methylphosphoramidate)
	Dalapon
	N,N-Diallyl-2-chloroacetamide
	1,2-Dibromo-3-chloropropane
	2,6-Di-tert-butyl-p-tolyl methylcarbamate
	Dicamba
	S-(2,3-Dichloroallyl)diisopropylthiocarbamate
	Dichloro diphenyl trichloroethane

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28694	2,6-Dichloro-4-nitroaniline
	2,4-Dichlorophenoxyacetic acid
	O-(2,4-Dichlorophenyl)O,O-diethyl phosphorothioate
	3',4'-Dichloropropionanilide
	2,2-Dichlorovinyl dimethyl phosphate
	Dieldrin
	O,O-Diethyl O-(3-chloro-4- Methyl-2-oxo-2H-1-benzopyran-7-yl)phosphorothioate
	O,O-Diethyl S-[2-(ethylthio)ethyl]phosphorodithioate
	O,O-Diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate
	O,O-Diethyl O-[-p(methylsulfinyl)phenyl] phosphorothioate
	O,O-Diethyl O-2-pyrazinyl phosphorothioate
	N,N-Diethyl-meta-toluamide
	1,2-Dihydro-3,6-pyridazinedione
	3-(O,O-Diisopropyl phosphorodithioate)ester of N-(2-mercaptoethyl) benzenesulfonamide
	Dimethoate
	O,O-Dimethyl O-p-nitrophenyl phosphorothioate
	O,O-Dimethyl S-[(4-oxo-1,2,3-benzothiazin-3(4H)-yl)methyl] phosphorodithioate
	Dimethyl phosphate ester with 3-Hydroxy-N,N-dimethyl-cis-crotonamide
	Dimethyl tetrachloroterephthalate
	2,4-Dinitro-6-octyl phenyl crotonate;2,6-Dinitro-4-octyl phenyl crotonate
	Dinoseb
	Dioxathion
	Diphacinone
	Diphenamid
	Dipropyl isocinchomeronate
	Disodium methanearsonate
	Diuron
	Dodecachlorooctahydro-1,3,4-metheno-1H-cyclobuta[cd]pentalene
	Dodine
	Endosulfan
	Endothall
	Endrin
	Ethyl 4,4-dichlorobenzilate

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28694	Ethion
	S-ethyl cyclohexylethylthiocarbamate
	S-ethyl diisobutylthiocarbamate
	O-ethyl S,S-dipropyl phosphorodithioate
	S-Ethyl dipropylthiocarbamate
	O-Ethyl hexahydro-1H-azepine-1-carbothioate
	O-Ethyl S-phenyl ethylphosphorodithioate
	M-(1-Ethylpropyl)phenyl methylcarbamate mixture with M-(1-Methylbutyl)phenyl methylcarbamate
	S [2-Ethylthio)ethyl] O,O-dimethyl phosphorodithioate
	hion
	ometuron
	orodifen
	Folpet
	Isopropyl N-(3-chlorophenyl)carbamate
	Isopropyl 4,4-dichlorobenzilate
	Lindane (gamma isomer of benzene hexachloride)
	Linuron
	Malathion
	Methomyl
	Methoxychlor
	Methyl bromide
	4-(Methylsulfonyl)-2,6-dinitro-N,N-dipropyl-aniline
	Monosodium acid methanearsonate
	Monuron
	Naled
	N-1-Naphthylphthalamic acid
	Nicotine
	Norea
	N-Octyl bicycloheptenedicarboximide
	Paradichlorobenzene
	Parathion
	Pentachloronitrobenzene
	Pentachlorophenol and sodium and potassium salts
	Phosphamidon
	Picloram
	Piperonal,bis[2-butoxyethoxy)ethyl]acetal
	Piperonyl butoxide
	S-Propyl butylethylthiocarbamate
	S-Propyl dipropylthiocarbamate
	Pyrethrins
	Ronnel
	Rotenone

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-1. Chemical Products of the Organic Chemicals and Technical Pesticides Industries Included in this Study by Standard Industrial Classification* (Continued)

SIC	Chemical Products
28694	Siduron
	Silvex
	Simazine
	Sodium fluoroacetate
	Terbacil
	Cis-N-[(1,1,2,2-Tetrachloroethyl)thio]-4-cyclohexene-1,2-dicarboximide
	Tetraethyl pyrophosphate
	O,O,O,O-Tetrapropyl dithiopyrophosphate
	O,O,O',O'-Tetramethyl O',O'-thiodi-p-phenylene phosphorothioate
	Toxaphene
	S,S,S-Tributyl phosphorotrithioate
	Tributyl phosphorotrithioite
	S-(2,3,3-Trichloroallyl)diisopropyl thiocarbamate
	Trichloroacetic acid
	2,3,6-Trichlorobenzoic acid and related polychlorobenzoic acids, dimethylamine salts
	2,4,6-Trichlorophenoxyacetic acid
	Trifluralin
	Warfarin
	Zinc naphthenate
28695	Ethanol

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*The nomenclature employed is taken from References 4, 7 and 13.

Table 4-2. Number of Plant Sites[1] by Standard Industrial Classification Organic Chemicals and Technical Pesticides Industries[2]

EPA Region	State	28610	28611	28612	28650	28651	28652	28653	28655	28691	28692	28693	28694	28695	Total[3]
4	Alabama	1	1	4	0	6	1	0	8	2	9	0	7	0	31
10	Alaska	0	0	0	0	2	0	0	0	0	2	0	0	0	2
9	Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Arkansas	0	0	0	0	1	0	0	0	1	5	0	2	0	7
9	California	0	0	0	0	10	2	1	4	3	22	3	9	1	44
8	Colorado	0	0	0	0	1	0	0	1	0	0	1	2	0	4
1	Connecticut	0	0	0	0	2	0	0	0	1	3	4	3	0	8
3	Delaware	0	0	0	0	3	0	0	3	0	4	0	1	0	8
3	District of Columbia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Florida	2	7	3	0	2	0	0	0	5	4	2	1	0	16
4	Georgia	0	1	4	0	2	0	0	1	2	5	0	3	0	15
9	Hawaii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Idaho	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Illinois	0	0	0	0	12	0	2	7	5	18	7	8	2	47
5	Indiana	0	0	0	1	4	0	0	2	1	10	2	3	1	18
7	Iowa	0	0	0	0	0	0	0	0	1	2	0	4	1	8
7	Kansas	0	0	0	0	2	0	0	0	0	4	0	3	0	8
4	Kentucky	0	0	0	0	4	1	1	1	1	15	1	0	0	18
6	Louisiana	0	2	5	0	16	0	0	1	4	29	4	8	2	52
1	Maine	0	0	0	0	1	0	0	0	0	0	0	0	0	1
3	Maryland	0	0	0	0	3	1	0	2	0	5	1	2	0	11
1	Massachusetts	0	0	0	0	4	4	2	0	0	6	3	0	0	12
5	Michigan	0	0	1	0	8	1	1	5	2	12	4	4	0	28
5	Minnesota	0	0	0	0	0	0	0	1	0	0	0	1	0	2
4	Mississippi	0	0	0	0	1	0	0	1	3	2	3	4	0	13
7	Missouri	0	0	0	0	1	0	0	1	2	3	1	7	0	17
8	Montana	0	0	0	0	0	0	0	0	0	1	0	0	0	1
7	Nebraska	0	0	0	0	0	0	0	0	1	0	0	0	0	1
9	Nevada	0	0	0	0	2	0	0	0	0	0	0	0	0	2
1	New Hampshire	0	0	0	0	0	0	0	0	1	1	0	0	0	1
2	New Jersey	0	0	0	0	42	15	10	4	12	66	21	16	1	137
6	New Mexico	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	New York	0	0	0	0	13	3	5	2	6	17	7	5	0	41
4	North Carolina	0	0	3	0	5	4	2	0	3	10	5	3	0	28
8	North Dakota	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Ohio	0	0	1	0	17	4	3	7	5	28	8	6	0	61
6	Oklahoma	0	0	1	0	0	0	0	0	0	2	0	0	0	3
10	Oregon	0	0	0	0	0	0	0	1	0	8	0	2	0	11
3	Pennsylvania	0	0	0	0	14	4	3	7	1	19	6	4	1	44
2	Puerto Rico	0	0	0	0	4	0	0	0	1	5	0	0	1	8
1	Rhode Island	0	0	0	0	1	1	1	0	3	2	1	0	0	7
4	South Carolina	0	0	2	0	7	2	0	0	0	8	0	1	0	18
8	South Dakota	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Tennessee	0	0	1	0	7	1	0	2	5	8	3	5	0	22
6	Texas	0	0	2	0	33	0	0	13	10	87	5	9	2	98
8	Utah	0	0	0	0	1	0	0	2	0	0	0	0	0	3
1	Vermont	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Virginia	0	0	0	0	3	1	0	2	1	6	0	1	0	10
10	Washington	0	0	2	0	3	0	0	0	1	3	0	4	1	13
3	West Virginia	0	0	0	0	8	2	2	3	2	8	8	5	0	23
5	Wisconsin	0	0	0	0	4	0	0	0	1	2	0	1	1	7
8	Wyoming	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NATIONAL TOTALS		3	11	29	1	247	47	33	81	96	424	[illegible]	134	13	994

REGION TOTALS														
1	0	0	0	0	10	5	3	0	5	12	8	3	0	29
2	0	0	0	0	59	18	15	6	19	90	28	21	2	186
3	0	0	0	0	31	8	3	17	4	42	13	11	1	96
4	3	9	17	0	34	9	3	13	21	61	14	25	0	159
5	0	0	2	1	45	5	6	22	14	71	21	22	3	209
6	0	2	8	0	50	0	0	14	15	123	9	19	4	166
7	0	0	0	0	3	0	0	1	4	9	1	14	1	29
8	0	0	0	0	2	0	0	3	0	1	1	2	0	7
9	0	0	0	0	12	2	1	2	3	22	3	9	1	46
10	0	0	2	0	3	0	0	1	1	13	0	6	1	25

NOTES:

[1] Number of plant sites at which one or more commodity chemicals listed in Table 3-1 under the given Standard Industrial Classification was manufactured.

[2] References 11 and 12, and the industry sources listed in Table 3-1.

[3] The number of plant sites in this column may be less than the total obtained by adding the numbers shown for each five digit SIC product group, since there are numerous plant sites at which several SIC product groups are manufactured.

Table 4-3. Plant Size by Daily Capacity, Metric Tons Organic Chemicals and Technical Pesticides Industries(3,4,8,11,12)*

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695
4	Alabama	1		1 4	1 1 1	1		4 2	2	1 2 2		1 1	
10	Alaska									1 1			
9	Arizona											1	
6	Arkansas									2			
9	California				2 2	2	1	2 1	2	3 4 8 1	2 1	4 1	
8	Colorado				1			1			1	1	
1	Connecticut				1					1	1	1 1	
3	Delaware				2			1		4			
3	District of Columbia												
4	Florida	1	6 6	2 2	2				2 2	1 1	1	1	
4	Georgia		1	1 4	1			1 1	1	1 3	1		
9	Hawaii												
10	Idaho												
5	Illinois				5 4			1 1	1 1	4 2 4 1	1 1	1 2	1
5	Indiana				1 2			1 1 2		2 5 2	1 1	2	
7	Iowa									1 1 1		2 1	
7	Kansas				1 1					3		2	
4	Kentucky				2 2	1	1	1	1	2 5 6 1	1		
6	Louisiana		4	6	7 4 3				1 1 1	3 16 9	1	1 1	
1	Maine												
3	Maryland				1 2	1		1 1		1 1		1	
1	Massachusetts				2	4	2			1 1 1	1		
5	Michigan				1 1	1	1	4	1 1	1 1 3	1 1	2 1 1	
5	Minnesota							1					
4	Mississippi				1				1	1 1	1	2 1	
7	Missouri				1				1	1 1 1	1	1 2	
8	Montana									1			
7	Nebraska								1				
9	Nevada				1								
1	New Hampshire								1	1			
2	New Jersey				9 8 6 1	11 4	8 2	1 1	2 3	15 10 8 1	14 2	2 6	1
6	New Mexico												
2	New York				3 3	3 2	4	1	1 1	1 4 3	2 2	2 2	
4	North Carolina			2	1 1	3 1	2		2	1 5	1 1	2	
8	North Dakota												
5	Ohio			2	1 6	3 1	2	6 2	4	6 7 2	4 1	3	
6	Oklahoma									1 1			
10	Oregon							1		1 2		1	
3	Pennsylvania				8 7	4	2	2 2		3 5 6	4 1	4	1
2	Puerto Rico				5 3 1				1	3 1 4			1
1	Rhode Island					1	1		1		1		
4	South Carolina			2	2 2	1 1				1 1 2		1	
8	South Dakota												
4	Tennessee				1 2	1		1 1	1 1	1 1 1	1 1	1 1	
6	Texas			2 1	2 17 16 3			1 3 4 1	2 3 2	2 9 25 25	3	2 4	2
8	Utah				1			1 1					
1	Vermont												
3	Virginia				1 1	1				1 8 2		1	
10	Washington			1 1	1 1					5		1 1	1
3	West Virginia			2 5	2	2		1 1	2	2 8 2	1 2 1	1 1	
5	Wisconsin			1						1		1	
8	Wyoming												
NATIONAL TOTALS		1 1	10 7	4 25 4	[illegible] 9 66 10	40 9	26 2	25 26 1	21 21 5	[illegible]	40 23 1	54 37	1 2 3 1

REGION TOTALS	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695
1				4	5	3		1 1	1 2 2	1	1 1	
2				14 12 9 2	14 6	12 2	1 1	3 4 1	20 13 12 5	17 4	9 8	1 1
3				1 5 7	8	6	4 5	2	4 18 8 2	5 3 1	9 1	1
4	1 1	6 7	2 14 2	6 3 10 1	7 2	3	1 3 5	5 8	7 17 7 3	4 4	12 5	
5			2	3 13 5 1	4 1	3	2 6 11	6 1 1	11 15 17 1	11 4	8 2	1
6		4	8 1	2 17 20 6			1 3 4 1	3 4 3	[illegible]	3 3	5 2	2
7				1 2				1 1	2 5 3	1	7 3	
8				1 1			2 1 1		1	1	1	
9				4 2	2	1	2 1	2	3 4 8 1	2 1	4 2	
10			1 1	1 1 1			1		5 4		1 2	1

*See Appendix A "Methodology Details" for the procedures employed to obtain the estimates of individual plant sizes. The references cited as data sources were supplemented by the industry sources listed in Table A-1.

NOTE

Production data was not available for 38% SIC-plant site combinations.

CODE

A 0 - 9 metric tons/day
B 10 - 99 metric tons/day
C 100 - 999 metric tons/day
D 1000 or more metric tons/day

Table 4-4. Production Rate, Thousand Metric Tons Per Year, By Standard Industrial Classification Organic Chemicals and Technical Pesticides Industries(3,4,8,11,12)*

EPA Region	State	28610	28611	28612	28650	28651	28652	28653	28655	28691	28692	28693	28694	28695	Total
4	Alabama	47	NA	50		462	2		196	16	278		64		1,115
10	Alaska										290				290
9	Arizona														
6	Arkansas					NA				NA	128		8	NA	136
9	California					274	.4	.7	150	4	1,966	15	41		2,451
8	Colorado					1			.5			2	13		16
1	Connecticut					.5				NA	104	6	5		116
3	Delaware					288			45		433				766
3	District of Columbia														
4	Florida	33	90	159		292				34	583	.1	.3		1,192
4	Georgia		7	42		68			50	3	276		7		453
9	Hawaii														
10	Idaho														
5	Illinois					420		NA	127	5	1,168	9	21	437	2,187
5	Indiana				NA	51			122	NA	450	7	.9	NA	631
7	Iowa									9	289		24	NA	322
7	Kansas					59					114		4		177
4	Kentucky					33	.5	.2	41	32	1,842	.2			1,951
6	Louisiana		4	84		2,279			NA	94	11,838	24	35	NA	14,358
1	Maine					NA									
3	Maryland					161	.5		212		131	NA	2		506
1	Massachusetts					5	1	.5			143	7			154
5	Michigan					625	.01	.1	246	57	274	6	30		1,238
5	Minnesota								23				2		25
4	Mississippi					107			NA	3	54	12	27		204
7	Missouri					67			NA	1	114	24	23		229
8	Montana										36				36
7	Nebraska									16					16
9	Nevada					32									32
1	New Hampshire									6	5				11
2	New Jersey					1,230	44	12	25	27	1,335	78	59	3	2,814
6	New Mexico														
2	New York					39	17	2	38	17	247	13	11		384
4	North Carolina			14		345	12	2		25	345	6	.5		750
8	North Dakota														
5	Ohio			93		77	5	.5	215	22	963	12	17		1,317
6	Oklahoma			NA							37				37
10	Oregon								23		451		4		478
3	Pennsylvania					937	7	.5	154	NA	584	17	2	226	1,928
2	Puerto Rico					645				74	7,388			9	8,116
1	Rhode Island					NA	.7	.2		.2	NA	15			16
4	South Carolina			29		205	5				246		.5		486
8	South Dakota														
4	Tennessee			NA		317	.2		38	23	841	15	22		1,252
6	Texas			71		5,575			1,143	240	27,859	6	56	245	35,197
8	Utah					15			42						57
1	Vermont														
3	Virginia					222	.4		NA	NA	234		1		456
10	Washington			41		113				NA	54		7	15	230
3	West Virginia					610	2	1	82	33	1,212	52	30		2,024
5	Wisconsin					40				NA	54		7		101
8	Wyoming														
NATIONAL TOTALS		80	101	490	NA	15,589	105	33	2,973	743	62,366	327	526	935	84,248

REGION TOTALS	28610	28611	28612	28650	28651	28652	28653	28655	28691	28692	28693	28694	28695	Total
1					6	4	1		6	252	28	5		297
2					1,922	61	15	63	118	8,970	64	70	12	11,315
3					2,217	9	4	494	33	2,594	69	34	226	5,680
4	80	97	294		1,823	20	2	325	136	4,467	36	122		7,402
5			93		1,213	5	7	713	84	2,909	34	78	437	5,494
6		4	155	NA	7,854			1,143	334	39,861	30	101	244	49,727
7					121				26	517	24	51		739
8					16			43		36	2	13		110
9					306	4	4	150	4	1,967	15	41		2,484
10			41		113			23		795		11	15	998

*See Appendix A for the procedures used to develop these estimates. The references cited were supplemented by the industry sources listed in Table A-1.

NOTE

All production rates except those for SIC 28694 are for CY 1973. The production rates for SIC 28694 are for CY 1977.

NA = Estimates of production rate were not applicable, due to lack of appropriate data.

Table 4-5. Process Types Used for Manufacture, by Standard Industrial Classification – Organic Chemicals and Technical Pesticides Industries*

Process Type

1. Acylation
2. Alkylation
3. Ammonolysis
4. Carbonylation
5. Coupling
6. Cyclization
7. Dehalogenation
8. Dehydration
9. Dehydrogenation
10. Dehydrohalogenation
11. Distillation
12. Esterification
13. Extraction
14. Halogenation
15. Hydration
16. Hydrogenation
17. Hydrolysis

Process Type

18. Hydroxylation
19. Isomerization
20. Miscellaneous synthesis
21. Neutralization
22. Nitration
23. Oxidation
24. Polymerization
25. Pyrolysis
26. Reduction
27. Sulfonation
28. Multi-step synthesis
29. Dealkylation
30. Fermentation
31. Crystallization
32. Ethylene by-product
33. Condensation
34. Precipitation

*See Appendix A for the procedures used to classify chemical product-plant site combinations by process type. The process type names employed were compiled for this study on the basis of the process chemistries involved in the manufacture of the individual commodities.

Table 4-5. Process Types Used for Manufacture, by Standard Industrial Classification — Organic Chemicals and Technical Pesticides Industries (Continued)

EPA Region	State	28610		28611		28612			28650	28651																				
		11	13	11	13	11	13	16	11	1	2	3	5	6	8	9	11	12	13	14	16	20	22	23	24	26	27	28	29	30
4	Alabama		1	1		2	5				2								2								3	1		
10	Alaska																													
9	Arizona																													
6	Arkansas																			1										
9	California										3								4	2				5				1		
8	Colorado																		1											
1	Connecticut																		1			1						1		
3	Delaware										1									3								1		
3	District of Columbia																													
4	Florida	1	1	13	7	4	2												1					1						
4	Georgia			2	1	8	2													2				1						
9	Hawaii																													
10	Idaho																													
5	Illinois										1	2	2	1		1				4	2	1	2	7		1	2	4		
5	Indiana								1			1	1														1		1	
7	Iowa																													
7	Kansas												1			1					1			2						
4	Kentucky																					1		1				1		
6	Louisiana			6		6	2				5		2	1	1	4	1			1	1	1	2	3				5		
1	Maine																			4							2	1		
3	Maryland										2								1							1				
1	Massachusetts																													
5	Michigan										2		1						1	5		1					2	6		
5	Minnesota																													
4	Mississippi												1										1							
7	Missouri																							2				1		
8	Montana																													
7	Nebraska																													
9	Nevada																			1					1					
1	New Hampshire																													
2	New Jersey									1	11		4	1					4	15	2	15	3	8			14	11		
6	New Mexico																													
2	New York										1	1						1		11		11					2	4		
4	North Carolina					5	4				1	1										2		1				2		
8	North Dakota																													
5	Ohio					2	1				2		1	1	2				1	2	1			4			3	5		
6	Oklahoma					1	1	1																						
10	Oregon																													
3	Pennsylvania																		4	1		1		1			3	4		
2	Puerto Rico												2																	
1	Rhode Island																										1			
4	South Carolina																										4	4		
8	South Dakota																													
4	Tennessee									1	2									1		1		2		1	3	2		
6	Texas										14		6			4			1		6	4		6		2		5		
8	Utah																													
1	Vermont																													
3	Virginia																													
10	Washington																													
3	West Virginia																			1							3	4		
5	Wisconsin																		1	2										
8	Wyoming																													
NATIONAL TOTALS		1	2	22	8	18	13	1	1	2	42	5	25	6	2	21	3	1	60	44	15	17	18	62	1	6	41	47	7	1

REGION TOTALS																														
1																			1	4							2	2		
2										1	13	1	4	1				1	6	[illegible]	[illegible]	[illegible]	5	10			16	15		
3											[illegible]																			
4		1	2	16	8	[illegible]	[illegible]				[illegible]																			
5											[illegible]																			
6				6		20	6				19		[illegible]																	
7																														
8																			[illegible]											
9																			4					5						
10																														

Table 4-5. Process Types Used for Manufacture, by Standard Industrial Classification — Organic Chemicals and Technical

EPA Region	State	28652				28653			28655									28691														
		20	27	28	29	2	20	28	2	9	11	13	20	25	28	29	31	2	3	5	6	8	9	11	12	13	14	20	21	23	27	28
4	Alabama			2							5	9					4															
10	Alaska																															
9	Arizona																															
6	Arkansas																										1					
9	California			2				3			1	4		2							1				1	2						
8	Colorado											2																				
1	Connecticut																3															1
3	Delaware																															
3	District of Columbia																															
4	Florida																					1		1		6						
4	Georgia										1	1														4		1				
9	Hawaii																															
10	Idaho																															
5	Illinois							4			5	2					6	1									1					1
5	Indiana										2	2					2													1		
7	Iowa																					1										
7	Kansas			4																												
4	Kentucky			4				2									1			1												
6	Louisiana												1					1		2						2						
1	Maine																															
3	Maryland			2							2	[illegible]																				
1	Massachusetts			10				5																								
5	Michigan			1				3			2	3				1	1	1		1												
5	Minnesota										1	1																				
4	Mississippi													1										1		1						
7	Missouri										1							1											1			
8	Montana																															
7	Nebraska																					1										
9	Nevada																															
1	New Hampshire																		1													
2	New Jersey			49			2	40			1	2					1		2	1	1				2	1	1	2	2	1	1	
6	New Mexico																															
2	New York		1	14	1		1	15			1	3		1					1								1	4				
4	North Carolina			14				5											1					1								
8	North Dakota																															
5	Ohio	1		12		1	1	6			5	11					5								2			1				
6	Oklahoma																															
10	Oregon										1	1																				
3	Pennsylvania			16				8	1		6	8			1		1												1			
2	Puerto Rico																			1												
1	Rhode Island			2				2																	1	1			1			
4	South Carolina			5																												
8	South Dakota																															
4	Tennessee			1							1	4						2				1							1			
6	Texas								1	3	3	9	2	2						1	1		1					1				1
8	Utah										1	1																				
1	Vermont																															
3	Virginia			1								1		1																		1
10	Washington																									2						
3	West Virginia			3				3	1		2	2			1		1		1											1		
5	Wisconsin																	1														
8	Wyoming																															
NATIONAL TOTALS		1	1	138	1	1	4	[illegible]	3	3	41	71	3	7	2	1	27	7	8	10	5	4	1	3	9	24	6	12	6	5	1	1
REGION TOTALS																																
1				12				7											1						1	1			1			1
2			1	63	1		3	55			2	5		1			1		3	2	1				2	1	4	6	2	1	1	
3				22				16	2		10	14		1	2		5		1										1	1		1
4				26				7			7	14		1		1	6	2	1	1		1		1		16		1	1			
5		1		13		1	1	13			15	19					16	3		1					4		1	1		1		1
6									1	3	3	9	3	2				1		5	3		1			2	1	1				1
7											1							1				2							1			
8											1	5																				
9				2				3			1	4		2							1				1	2						
10											1	1														2						

Table 4-5. Process Types Used for Manufacture, by Standard Industrial Classification – Organic Chemicals and Technical Pesticides Industries (Continued)

		28692																									
EPA Region	State	2	3	4	5	6	8	9	11	12	13	14	15	16	17	20	21	23	24	25	26	27	29	30	31	32	34
4	Alabama	2	1							2	1	3						2				1	1				
10	Alaska											1		1													
9	Arizona																										
6	Arkansas											5						2									
9	California	2	1				1	1		4	2	12	2		1		2	6		14			2		1		
8	Colorado																										
1	Connecticut											1		1									1	1			
3	Delaware							1					1	1				1		4		1	1				
3	District of Columbia																										
4	Florida		5						1	1		1		2	1	1		1					1				
4	Georgia									1		1				1	1	1					2				
9	Hawaii																										
10	Idaho																										
5	Illinois	2					1	1		2		3	2	1	1	1	1	1	2	5			2				
5	Indiana	1	1							2		6					1	2		4				1			
7	Iowa																			2				1			
7	Kansas											4						2		2							
4	Kentucky		3									15	5			1		6		6			1				
6	Louisiana	1	4				1	4		2		17	16	5	1	1		15		19			4				
1	Maine																										
3	Maryland									2		1	1	1		1	1						[illegible]				
1	Massachusetts									1		1					1	1					[illegible]				
5	Michigan	1	6		1			1	1	2		[illegible]				1		1	[illegible]	2			[illegible]				
5	Minnesota																										
4	Mississippi																	[illegible]									
7	Missouri						[illegible]										4	[illegible]					[illegible]				
8	Montana																	[illegible]									
7	Nebraska																										
9	Nevada																										
1	New Hampshire																						[illegible]				
2	New Jersey	2	5		1		1	1		14		25		1		4	24	11	1	2			[illegible]	[illegible]			1
6	New Mexico																										
2	New York	1								2		1	1			1	6	2		1			[illegible]				
4	North Carolina									2						2	4	5									
8	North Dakota																										
5	Ohio	1	1					1		5		1				1	11	4		4			4	[illegible]			
6	Oklahoma																			1							
10	Oregon																	1									
3	Pennsylvania		1				2	1		6		1		1		2	5	5		1			1	1			
2	Puerto Rico			1								3	5			1		5		5							
1	Rhode Island														1												
4	South Carolina	1								2		2				4	1	4									
8	South Dakota																										
4	Tennessee	1	1	[illegible]			[illegible]	[illegible]	[illegible]			1				1	2	2					1				
6	Texas	1	14	2	1	1	2	8		10	4	25	[illegible]	[illegible]	6	[illegible]		[illegible]	3	[illegible]	1	1	[illegible]	1		2	
8	Utah																										
1	Vermont																										
3	Virginia		4				1					1				4				1			1				
10	Washington																										
3	West Virginia	1	1	[illegible]			2	1		[illegible]		[illegible]	4		1	[illegible]	[illegible]	[illegible]		1			4				
5	Wisconsin																[illegible]										
8	Wyoming																					[illegible]					
NATIONAL TOTALS		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REGION TOTALS	2	3	4	5	6	8	9	11	12	13	14	15	16	17	20	21	23	24	25	26	27	29	30	31	32	34
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4-5. Process Types Used for Manufacture, by Standard Industrial Classification – Organic Chemicals and Technical Pesticides Industries (Continued)

EPA Region	State	28693																	28694								28695			
		1	2	3	5	6	11	12	13	14	15	16	20	21	23	26	28	30	13	14	26	28	29	30	33	34	12	14	15	25
4	Alabama																					24								
10	Alaska																													
9	Arizona																													
6	Arkansas																					5								
9	California							4										1	1			16				1			1	
8	Colorado																	1				10								
1	Connecticut		1	2		1							3	1			2					3								
3	Delaware																									1				
3	District of Columbia																													
4	Florida						1	1														2								
4	Georgia																					5								
9	Hawaii																													
10	Idaho																													
5	Illinois				1			6					2		1		1			2		17				1	1		1	
5	Indiana		1					2										1				3							1	
7	Iowa										1											6							1	
7	Kansas																					4								
4	Kentucky			1													1													1
6	Louisiana		2	1				5									1			1		12							2	
1	Maine																													
3	Maryland							1														4								
1	Massachusetts		1					1									1													
5	Michigan							1									2			2		17		1						
5	Minnesota																					11								
4	Mississippi		1					4														8								
7	Missouri							3						3			1					14								
8	Montana																													
7	Nebraska																													
9	Nevada																													
1	New Hampshire																													
2	New Jersey	2	4	2			5	28	2					1			1				1	40				2		1		
6	New Mexico																													
2	New York		2	1			1	9					1									14								
4	North Carolina				1			6						2								5								
8	North Dakota																													
5	Ohio		2	3	1			9					2				4			1	1	8				1				
6	Oklahoma																													
10	Oregon																					15								
3	Pennsylvania		1					10					1		1							12							1	
2	Puerto Rico																												1	
1	Rhode Island							3																						
4	South Carolina																					1								
8	South Dakota																													
4	Tennessee			1	1			4								1						8								
6	Texas		1	1				2									1					17			1	1			2	
8	Utah																													
1	Vermont																													
3	Virginia																					2	1							
10	Washington																												1	
3	West Virginia			2				7		1		1	1				2			1		12				2				
5	Wisconsin																					6								
8	Wyoming																													
NATIONAL TOTALS		2	17	14	4	1	7	108	2	1	1	1	10	7	2	1	16	3	1	9	2	307	1	1	1	11	1	1	11	1

REGION TOTALS																												
1		2	2		1		4					3	1			3					3								
2	2	6	3			6	37	2				1	1			1				1	14						1	1	
3		1	2				18		1		1	2		1		2			1		30							1	
4		1	2	2		1	15						2		1	1					51								1
5		4	3	2			28					4		1		8	1		5	1	67					1		2	
6		3	2				7									2			1		34							4	
7							3			1			1			1					24							1	
8																	1				10								
9							4										1	1			16							1	
10																					17							1	

Table 4-1 indicates, for each five-digit SIC product group, the chemical products(3,4,7-10) of the organic chemicals industry covered in this study.[1] It should be noted that SIC 28694 (technical pesticides) covers commodities which are given dual consideration herein, as the products of the organic chemicals industry, and as the products of the pesticides industries.

Table 4-2 presents, for each five-digit SIC product group, a tabulation of the number of plant sites(11,12) (industry sources listed in Table A-1) in each state at which one or more of the chemicals in Table 4-1 for the product group are manufactured. Since there are numerous plant sites at which chemicals in each of several five digit SIC product groups are manufactured, the tabulation is partially redundant. Excluding double accounting, the true aggregate number of organic chemical plant locations covered in this study was 899.

For comparison, the true aggregate number was 1204 for locations where any "commercial scale" organic chemical was manufactured(11,12) (commercial scale here indicates a United States production total in 1973 of 1 million pounds or more).[2] The study thus encompassed about 75 percent of the commercial scale production sites.

The three states with the greatest concentrations of plant sites covered in this study were: New Jersey (137), Texas (98), and Ohio (61). The three product groups with the largest number of plant sites were SIC 28692, miscellaneous acyclic chemicals (424); SIC 28651, cyclic intermediates (247); and SIC 28694, technical pesticides (134).

The distribution of plant sizes[3] for each of the 12 production groups, rated in terms of aggregate daily production capacity for the chemicals in the group, is given in Table 4-3. Roughly 65 percent of the product group-plant site combinations were rated at less than 100 metric tons per day. At the upper end of the scale, only one combination in 16 was rated at 1000 or more metric tons per day.

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[1] See Appendix A for the criteria used to select organic chemicals covered in this study.

[2] Organic chemicals (other than pesticides) which were not listed by the U.S. International Trade Commission (Reference 3) because there was only one manufacturer were also excluded. Polychlorobiphenyl (PCB) and other chemicals with potentially hazardous waste streams were therefore excluded on this basis.

[3] See Appendix A for the procedures employed to obtain the estimates of individual plant sizes, and the references used as data sources.

Table 4-4 lists the distribution of production[1] for the organic chemicals industry. The figures given are composited from production capacity and production rates for 1972 and 1973. They indicate that the two product groups which account for more than 90% of the organic chemical production covered in this study are SIC 28692, miscellaneous acyclic chemicals, and SIC 28651, cyclic intermediates. The miscellaneous acyclic chemicals amount to almost three-fourths of the total organic production given in Table 4-4. The locales with the greatest concentrations of production are Texas, Louisiana, and Puerto Rico.[2]

The distribution of process types[3] used for manufacture of organic chemicals for each Standard Industrial Classification product group is given in Table 4-5. Approximately 2700 of the 3206 chemical product-plant site combinations covered in this study have been classified by process type in Table 4-5. Each such combination represented a production line which manufactured an organic chemical commodity. Due to the adaptability of much of the organic chemical process equipment and unit operations, the same physical equipment, in many cases, was used to produce different chemicals at different times of the year. This was true for both batch operations and continuous production systems.

4.3 PESTICIDES INDUSTRIES

The data presented in this section are subject to the limitations noted in Section 3 "Methodology" and in "Appendix A" on the pesticide preparations and formulations industry. To round out the picture of the pesticides industries, a portion of the data presented earlier in Section 4.2 on SIC 28694 (the technical pesticides product group) has been repeated.

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[1] See Appendix A for the procedures and references used to develop these estimates.

[2] In some cases, wastes generated at plant sites located in Puerto Rico are shipped to sites located within the United States for treatment and disposal. In addition, EPA considers Puerto Rico as part of Region II and treats it as such in its studies. For these reasons, Puerto Rico was also included in this study.

[3] See Appendix A for the procedures used to classify chemical product-plant site combinations by process type. The process type names employed were compiled for this study on the basis of the process chemistries involved in the manufacture of the individual commodities.

Table 4-6 presents data(6,11) on the distribution by state of plants in the technical pesticide manufacturing (SIC 28694) and formulating (SIC 2879) industries. The national total number of production sites for the two industries are 134 and 388, respectively. With the exception of plants producing certain highly dangerous products, the listing of production sites for SIC 28694 covers only those facilities producing at least one pesticide for which the annual total national production is close to or in excess of 453 metric tons (1 million pounds). In Table 4-6, the formulating plants are further divided into the following four product group SIC subcategories:(7)

- SIC 28791; Establishments engaged in the formulation of insecticidal preparations for agriculture, garden and health service.
- SIC 28792; Establishments engaged in the formulation of herbicidal preparations for agriculture, garden and health service.
- SIC 28793; Establishments engaged in the formulation of agricultural chemicals, fungicides, soil fumigants, and products not elsewhere classified.
- SIC 28794; Establishments engaged in the formulation of household insecticides and repellants.
- SIC 28790; Establishments engaged in the formulation of agricultural chemicals not specified by kind.

The national totals for the formulation sites in SIC 28791, 28792, 28793, 28794 and 28790 are 155, 97, 110, 158 and 307, respectively. These numbers and the plant distribution data for the states are based on an advance copy of the information which will be published in the "1972 Census of Manufacturers" by the Census Bureau. Since pesticides in each of several of the above subcategories may be formulated at a formulation site, the total number obtained by adding sites for each of the five subcategories exceeds that shown for the parent SIC 2879 (827 vs. 388). Although some pesticide manufacturing plants are operated as integrated facilities for both pesticide production and formulation, in general, pesticide formulation is conducted at a separate site and often by an independent formulator.

Table 4-6. Number of Plant Sites by Standard Industrial Classification – Pesticides Industries(6,11)

EPA Region	State	Technical Pesticides SIC 28694[1]	Pesticides Preparations and Formulations – SIC 2879[4] SIC 28791[2]	SIC 28792[2]	SIC 28793[2]	SIC 28794[2]	SIC 28790[2]	Total[3]
4	Alabama	7	7	4	4	1	7	8
10	Alaska							
9	Arizona						1	3
6	Arkansas	2	4	1	1		3	8
9	California	9	21	12	18	16	66	53
8	Colorado	2	3	2	2	1	5	6
1	Connecticut	3					2	2
3	Delaware	1					1	1
3	District of Columbia							
4	Florida	1	6	4	6	5	22	25
4	Georgia	1	9	4	8	15	8	14
9	Hawaii					7	2	1
10	Idaho						1	1
5	Illinois	6	8	4	1	17	16	10
5	Indiana	3	1	2	1	8	9	5
7	Iowa	4	5	3	2	2	6	10
7	Kansas	3	1	3	2	1	1	3
4	Kentucky		2	1	1	1	1	3
6	Louisiana	8	7	6	1	1	7	15
1	Maine							
3	Maryland	2	2	1		1	7	4
1	Massachusetts		2	2	1	1	6	6
5	Michigan	4	4	3	8	4	6	5
5	Minnesota	1	1	2		1	3	5
4	Mississippi	4	6	3	3	1	9	13
7	Missouri	7	5	4	3	10	11	21
8	Montana						2	3
7	Nebraska		1	1	1	7	2	3
9	Nevada		7				2	3
1	New Hampshire					2		9
2	New Jersey	16	9	3	4	11	4	5
6	New Mexico							
2	New York	3	4	2	2	11	13	17
4	North Carolina	3	6	4	5		9	12
8	North Dakota							
5	Ohio	6	6	4	5	10	17	13
6	Oklahoma						1	3
10	Oregon	2	7	2	2	2	5	5
3	Pennsylvania	4	8	3	1	4	17	15
2	Puerto Rico							NA
1	Rhode Island					1		
4	South Carolina	7	5	3	1	3	5	9
8	South Dakota							
4	Tennessee	5	1	1	1	2	7	9
6	Texas	9	17	11	11	9	23	37
8	Utah						1	3
1	Vermont							
3	Virginia	1	1	7	1	7	1	8
10	Washington	4	2	1	2		1	8
3	West Virginia	5	1				1	1
5	Wisconsin	1			1	4	4	5
8	Wyoming							
	NATIONAL TOTALS	138	155	97	110	158	837	388

NA - Estimate of number of plant sites not applicable, due to lack of appropriate data

[1] Number of plant sites at which Technical Organic Pest Control Chemicals, whose total national annual production was in excess of 1 million pounds, were manufactured

[2] Number of manufacturing establishments which reported shipments in this product class in the Bureau of the Census' 1972 Census of Manufacturers

[3] Number of manufacturing establishments classified within this industry in the Bureau of Census' 1972 Census of Manufacturers

[4] The Pesticides Preparations and Formulations industry is divided into five product groups (7):

SIC 28791 Insecticidal preparations for agriculture, garden and health service
SIC 28792 Herbicidal preparations for agriculture, garden and health service
SIC 28793 Agricultural chemicals, fungicides, soil fumigants, and NEC
SIC 28794 Household insecticides and repellants
SIC 28790 Agricultural Chemicals NSK - (Data includes companies with <10 employees)
NEC - not elsewhere classified
NSK - not specified by kind

The commodities manufactured under product group SIC 28694 are listed in Table 4-1. The production capacities for plants manufacturing technical pesticides (SIC 28694) are given in Table 4-3. Data on production capacities for plants engaged in pesticide preparation and formulation manufacture are not available.

Table 4-7(3,6,11,14) presents estimates* of production for calendar year 1972, in thousands of metric tons, for the pesticides industries. California, Texas, and New Jersey are the states which led the nation in 1972 in overall pesticide production.

The process type designations for technical pesticide manufacturing plants (SIC 28694) are given in Table 4-5. Data on process types employed in formulation and preparation plants is not available, although the majority engage in simple dry ingredient blending and/or solution preparation operations.

4.4 EXPLOSIVES INDUSTRIES

Establishments included in SIC 2892 are subclassified into SIC 28921 and SIC 28922.(7) The first subclassification covers privately owned and operated establishments engaged in the manufacture of explosives for commercial uses and, in limited cases, under special contracts, for military and space applications. Commercial uses of explosives are primarily in mining and construction activities. SIC 28922 covers all GOCO facilities engaged in the manufacture/formulation of explosives for military uses.

4.4.1 Commercial Explosives Industry

Major explosives of commercial importance are listed in Table 4-8. From the usage standpoint, commercial explosives may be grouped into fixed high explosives and blasting agents. Table 4-9 lists the quantities of various fixed high explosives and blasting agents which were sold for consumption in the United States in 1973.(15) In the absence of actual production data, the sale-for-consumption data in this table (and in related

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*See Appendix A for the procedures used to develop these estimates. The references cited were supplemented by the industry sources listed in Table A-1.

Table 4-7. Production Rate, Thousand Metric Tons Per Year, CY 1972 by Standard Industrial Classification – Pesticides Industries(3,6,11)*

EPA Region	State	TECHNICAL PESTICIDES SIC 28694	PESTICIDES PREPARATIONS AND FORMULATIONS SIC 2879	TOTAL
4	Alabama	64	26	90
10	Alaska			
9	Arizona		3	3
6	Arkansas	8	26	34
9	California	41	174	215
8	Colorado	13	26	39
1	Connecticut	5	7	12
3	Delaware		3	3
3	District of Columbia			
4	Florida	0.3	82	82
4	Georgia	7	46	53
9	Hawaii		3	3
10	Idaho		3	3
5	Illinois	[illegible]	59	[illegible]
5	Indiana	1	16	17
7	Iowa	24	33	57
7	Kansas	4	10	14
4	Kentucky		3	3
6	Louisiana	35	49	84
1	Maine			
3	Maryland	1	21	22
1	Massachusetts		20	20
5	Michigan	31	26	[illegible]
5	Minnesota	2	13	15
4	Mississippi	27	33	[illegible]
7	Missouri	23	26	[illegible]
8	Montana		2	2
7	Nebraska		10	10
9	Nevada		7	7
1	New Hampshire		3	3
2	New Jersey	62	40	102
6	New Mexico			
2	New York	11	56	67
4	North Carolina	43	39	82
8	North Dakota			
5	Ohio	17	43	60
6	Oklahoma		10	10
10	Oregon	4	16	20
3	Pennsylvania	2	49	51
2	Puerto Rico			
1	Rhode Island			
4	South Carolina	0.5	[illegible]	[illegible]
8	South Dakota			
4	Tennessee	23	[illegible]	[illegible]
6	Texas	58	[illegible]	[illegible]
8	Utah		3	3
1	Vermont			
3	Virginia		[illegible]	[illegible]
10	Washington	[illegible]	[illegible]	[illegible]
3	West Virginia	[illegible]	[illegible]	[illegible]
5	Wisconsin	[illegible]	[illegible]	[illegible]
8	Wyoming			
[illegible]		[illegible]	[illegible]	[illegible]

[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 4-8. Major Commercial Explosives

PRIMARY EXPLOSIVES AND INITIATING AGENTS
  - Blasting Caps
  - Detonating Cords
  - Electric Matches
  - Lead Azide
  - Mercury Fulminate
  - Safety Fuses

HIGH EXPLOSIVES
  - Dynamites
  - Nitroglycerin
  - Pentaerythritol Tetranitrate (PETN)

NITROCELLULOSE
  - Amine Nitrates (RDX, HMX)
  - Dinitrotoluene (DNT)
  - Trinitrotoluene (TNT)

BLASTING AGENTS AND PROPELLANTS
  - Ammonium Nitrate (Prilled or Grained)
  - Ammonium Nitrate-Fuel Oil Mixtures (ANFO)
  - Black Powder
  - Nitrocarbonitrates
  - Smokeless Powder
  - Water Gels and Slurries

Table 4-9. Industrial Explosives and Blasting Agents Sold for Consumption in the United States, 1973 (15)

Class	Description	Quantity 10^3 metric tons/year
Fixed High Explosives[a]		
Permissibles	Grades of high explosives approved by the U.S. Bureau of Mines for use, in a prescribed manner, in underground coal mines.	20
Other High Explosives	All high explosives except permissibles and those water gels or slurries containing high explosives; includes all formulations packaged in metal containers.	119
Total		139
Blasting Agents		
Cylindrically packaged[a]	Ammonium nitrate and fuel mixtures packaged in paper, burlap, or plastic containers having a cylindrical shape.	126
Water gels and slurries[a]	All water gels or slurries, packaged or in bulk, made by addition of more than 5% water to high explosives or blasting agents.	120
Other processed blasting agents and unprocessed ammonium nitrate[b]	Ammonium nitrate and fuel mixtures sold in bulk or packed in paper, plastic, burlap bags, or other containers designed for bulk loading; also prilled or grained ammonium nitrate.	865
Total		1,111
Grand Total		1,250

[a] Some quantities of this class of explosive or blasting agent are included with "other" processed blasting agents and unprocessed ammonium nitrate to avoid disclosing individual company data.

[b] Includes some quantities of fixed high explosives, cylindrically packaged blasting agents and water gels and slurries (see note (a) above).

subsequent tables) are assumed to be close to actual production. This is based on private explosives industry practice, which is to maintain relatively small constant inventories of explosives (other than ANFO* blasting agents), to prevent safety hazards due to degradation and quantity. ANFO blasting agents are generally formulated one day or less prior to use. The data in Table 4-9 indicate that ANFO blasting agents account for close to 89 percent of all the commercial explosives sold. Table 4-10 contains data on the estimated production of industrial explosives(15) by state, EPA Region and explosives class.

Plants in the commercial explosives industry fall into two general categories: (1) large and often complex facilities manufacturing explosives and many of the necessary chemical feedstocks and (b) small plants, usually located on or near the use site (mining field, etc.). Table 4-11 presents data on the number of licensed commercial explosives manufacturers in each state and EPA region, based on the information provided by the Bureau of Alcohol, Tobacco and Firearms (ATF), U.S. Treasury Department,(16) and by listings included in the SRI directory of Chemical Producers,(11) and by Dun and Bradstreet.(12) The companies listed in the latter two sources were contacted by telephone to verify that they were indeed involved in actual manufacturing of explosives. Those which were distributors or were no longer involved in explosives manufacturing were omitted from further consideration. Based on the data received from ATF, the size and production capability at each site could not be determined. Most of the facilities included in the ATF listing, however, are believed to be small ANFO formulators operating near the use site.

4.4.2 Military Explosives

The basic explosives for military use are manufactured by the U.S. Army. The basic explosives which are produced in volume quantities include trinitrotoluene (TNT), nitroglycerine, nitrocellulose, cyclotrimethylenetrinitramine (RDX) and cyclotetramethylenetetranitramine (HMX).

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*Ammonium nitrate-fuel oil

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Table 4-10. Estimated Production Rate, Metric Tons for CY 1973, By Explosive Class – Private Explosives Industry SIC 28921(15)

EPA Region	State	Fixed High Explosives: Permissibles	Fixed High Explosives: Other High Explosives	Blasting Agents: Cylindrically Packaged	Blasting Agents: Water Gels and Slurries	Blasting Agents: Other Blasting Agents & ANFO	Total
4	Alabama	2,454	3,426	12,217	575	68,238	86,909
10	Alaska	23	1,949	80	265		2,325
9	Arizona		2,605	108	23,362	59,325	85,400
6	Arkansas	3	938	235	777	6,139	8,091
9	California		2,333	191	6,451	21,206	30,194
8	Colorado	29	3,879	61	314	5,765	9,999
1	Connecticut		2,854	424	1,390	3,443	[illegible]
3	Delaware		55	5			61
3	District of Columbia						
4	Florida		11,352	2,198	4,260	3,105	20,915
4	Georgia	5	2,527	1,208	2,920	8,136	14,792
9	Hawaii		239	9	151	1,122	1,491
10	Idaho		1,474	90	118	3,592	5,262
5	Illinois	210	5,933	26,076	2,988	16,242	51,330
5	Indiana	25	1,141	16,985	1,714	35,564	55,427
7	Iowa	[illegible]	1,756	296	1,047	9,121	14,312
7	Kansas	4	730	917	900	1,713	4,261
4	Kentucky	6,947	5,801	24,712	1,200	116,564	155,125
6	Louisiana		803		4	1,602	2,409
1	Maine	5	702	79	105	885	1,772
3	Maryland		2,151	402	1,913	2,285	6,751
1	Massachusetts	5	1,613	133	199	1,422	3,368
5	Michigan	9	1,593	1,085	9,595	4,355	[illegible]
5	Minnesota		85	2,175	21,720	17,161	[illegible]
4	Mississippi		315	6	10	41	372
7	Missouri	14	5,342	1,682	2,236	[illegible]	[illegible]
8	Montana	3	1,474	34	13	[illegible]	[illegible]
7	Nebraska	[illegible]	241		4	595	[illegible]
9	Nevada		196	172	282	11,824	[illegible]
1	New Hampshire		775	3	[illegible]	296	1,084
2	New Jersey		2,444	38	792	901	[illegible]
6	New Mexico	5	1,775	3	3,297	18,062	23,142
2	New York	[illegible]	[illegible]	436	1,315	5,161	[illegible]
4	North Carolina	1	1,460	762	1,332	7,922	[illegible]
8	North Dakota					301	301
[illegible]	[illegible]	177	1,690	5,175	1,295	[illegible]	[illegible]
[illegible]	[illegible]	5	1,290	1,387	1,225	[illegible]	[illegible]
[illegible]	[illegible]		1,370	9	22	7,478	[illegible]
[illegible]	[illegible]	[illegible]	1,477	1,322	1,740	105,144	[illegible]
[illegible]	[illegible]						
[illegible]	[illegible]		[illegible]			[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	95	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]		15	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,371
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]						[illegible]	[illegible]

[illegible]						
[illegible]	[illegible]	[illegible]	544	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	541	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	44,[illegible]	[illegible]	[illegible]	134,408
[illegible]	[illegible]	[illegible]	[illegible]	47,[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	198	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4-11. Number of Plant Sites by Standard Industrial Classification – Explosives Industry

EPA Region	State	PRIVATE EXPLOSIVES INDUSTRY – SIC 28921 ATF Data[16]	Additional Data from TRW[11,12]	Total	GOCO PLANTS* – SIC 28922 Total	Active
4	Alabama	11		11	1	0
10	Alaska	0		0	0	0
9	Arizona	22	1	23	0	0
6	Arkansas	7		7	1	1
9	California	43		43	2	1
8	Colorado	19		19	1	0
1	Connecticut	9		9	0	0
3	Delaware	0		0	0	0
3	District of Columbia	1		1	0	0
4	Florida	11		11	0	0
4	Georgia	11		11	0	0
9	Hawaii	1		1	0	0
10	Idaho	6		6	0	0
5	Illinois	23	1	24	1	1
5	Indiana	14		14	2	2
7	Iowa	11		11	2	1
7	Kansas	7		7	2	1
4	Kentucky	21		21	0	0
6	Louisiana	4		4	1	1
1	Maine	2		2	0	0
3	Maryland	5		5	1	1
1	Massachusetts	2		2	0	0
5	Michigan	12		12	0	0
5	Minnesota	11		11	1	0
4	Mississippi	1		1	[illegible]	0
7	Missouri	17		17	2	0
8	Montana	12		12	0	0
7	Nebraska	2		2	[illegible]	0
9	Nevada	9		9	[illegible]	0
1	New Hampshire	4		4	0	0
2	New Jersey	6	2	8	2	1
6	New Mexico	13		13	4	2
2	New York	16		16	[illegible]	0
4	North Carolina	9		9	0	0
8	North Dakota	0		0	[illegible]	0
5	Ohio	30	1	31	[illegible]	[illegible]
6	Oklahoma	9		9	0	0
10	Oregon	3		3	0	0
3	Pennsylvania	72		72	1	0
2	Puerto Rico	0		0	[illegible]	0
1	Rhode Island	0		0	[illegible]	0
4	South Carolina	1		1	0	0
8	South Dakota	0		0	0	0
4	Tennessee	10		10	1	1
6	Texas	35	1	36	1	1
8	Utah	5		5	[illegible]	0
1	Vermont	0	1	1	0	0
3	Virginia	1		1	1	1
10	Washington	12		12	0	0
3	West Virginia	22	1	22	0	0
5	Wisconsin	11		11	1	1
8	Wyoming	6		6	0	0
NATIONAL TOTALS		576	11	586	35	21

REGION TOTALS					
1	17	1	18	0	0
2	22	2	24	2	1
3	102	1	108	3	2
4	77	1	78	4	1
5	101	2	103	7	4
6	67	2	68	2	2
7	43		42	7	3
8	46		46	1	0
9	75	1	76	2	1
10	21		21	0	0

*Includes six AEC plants, one each in Iowa, Texas, California and Ohio, and two in New Mexico, the Army GOCO and GOGO plants[17], and does not include commercial plants in Utah and California manufacturing propellant for the U.S. Air Force.

In addition to manufacturing explosives, the Army operates facilities for formulation of various explosives compositions and for loading, assembly and packing (LAP) of munitions. Manufacture and formulation of explosives and the LAP operations are conducted at GOCO Army ammunition plants (AAP's) and, to a negligibly small scale, at Army arsenals. Although not involved in large scale explosives manufacturing, the Navy and the Energy Research and Development Agency (ERDA; formerly Atomic Energy Commission) operate a number of LAP, explosive formulation, and research and development facilities which generate explosive-containing wastes.

The data on the distribution by state and EPA region of all GOGO and GOCO AAP's and arsenals are presented in Table 4-11. Because of current peacetime operation and the decline in demands for munitions, many of these facilities were inactive in 1973. Some of the AAP's (e.g., Scranton AAP in Pennsylvania and Riverbank AAP in California) are involved mainly in metal parts manufacturing and metal finishing operations and do not generate explosive-containing wastes. The distribution by state and EPA region for active facilities producing explosive-containing wastes are also shown in Table 4-11.

Nearly all Army ammunition plants were constructed during World War II (1940-45). These facilities still utilize much of the original equipment and processes. In recent years, the Army has initiated an extensive plant modernization program involving equipment replacement and construction of facilities which incorporate the latest advances in automation and chemical process technology. Some of the specific modernization projects have already been completed at a number of AAP's. Other modernization programs are currently either in the design construction stage or are awaiting funding considerations.

The 1973 quantities of basic explosives (TNT, DNT, NG, RDX, HMX, and tetryl), high explosive compositions (Composition B, etc.), propellants (NC), propellant formulations (single base, double base, etc., propellant) and munition items produced at Army facilities are presented in Table 4-12. These production quantities represent only the 1973 operation which is probably representative of the peacetime activities. During World War II, the Korean War, and the Vietnam operation, most of the AAP's (including those

Table 4-12. Production Rate, Metric Tons[1] for CY 1973, GOCO Plants,(18) Explosives Industry (SIC 28922)

EPA Region	State	Basic High Explosives	High Explosive Compositions	Propellants	Propellant Formulations	LAP Items (1000 rounds)
4	Alabama					
10	Alaska					
9	Arizona					
6	Arkansas					1,450
9	California					
8	Colorado					
1	Connecticut					
3	Delaware					
3	District of Columbia					
4	Florida					
4	Georgia					
9	Hawaii					
10	Idaho					
5	Illinois	109,780				1,740
5	Indiana					70,724
7	Iowa					2,473
7	Kansas					31,822
4	Kentucky					
6	Louisiana					[illegible]
1	Maine					
3	Maryland					312
1	Massachusetts					
5	Michigan					
5	Minnesota					
4	Mississippi					
7	Missouri					
8	Montana					
7	Nebraska					
9	Nevada					
1	New Hampshire					
2	New Jersey					712
6	New Mexico					
2	New York					
4	North Carolina					
8	North Dakota					
5	Ohio					
6	Oklahoma					
10	Oregon					
3	Pennsylvania					
2	Puerto Rico					
1	Rhode Island					
4	South Carolina					
8	South Dakota					
4	Tennessee	71,400	74,580			79,752
6	Texas					[illegible]
8	Utah					
1	Vermont					
3	Virginia	50,352		29,940	43,750	
10	Washington					
3	West Virginia					
5	Wisconsin	8,271		9,027	36,190	
8	Wyoming					
NATIONAL TOTALS		239,803	74,580	38,967	79,940	354,294

REGION TOTALS					
1					
2					712
3	50,352		29,940	43,750	312
4	71,400	74,580			79,752
5	118,051		9,027	36,190	72,464
6					167,059
7					34,295
8					
9					
10					

[1] LAP items are in 1,000 round units

now inactive) were in full production. The fluctuations in the production of TNT and tetryl at one AAP (Joliet, Illinois) from January 1968 to February 1974 are presented in Figures 4-1 and 4-2, respectively. The fluctuations are representative of the variability of production in response to Department of Defense demand. Since waste generation at explosive plants is directly proportional to production, the fluctuations also indicate the variability in waste quantities generated at the AAPs.

Many of the explosive-producing AAP's operate on-site facilities for the production and/or recovery from spent solutions of inorganic chemical feedstocks (e.g., nitric and sulfuric acids). These satellite operations are essentially identical to those in the commercial inorganic chemicals industry and were not included in the present study.

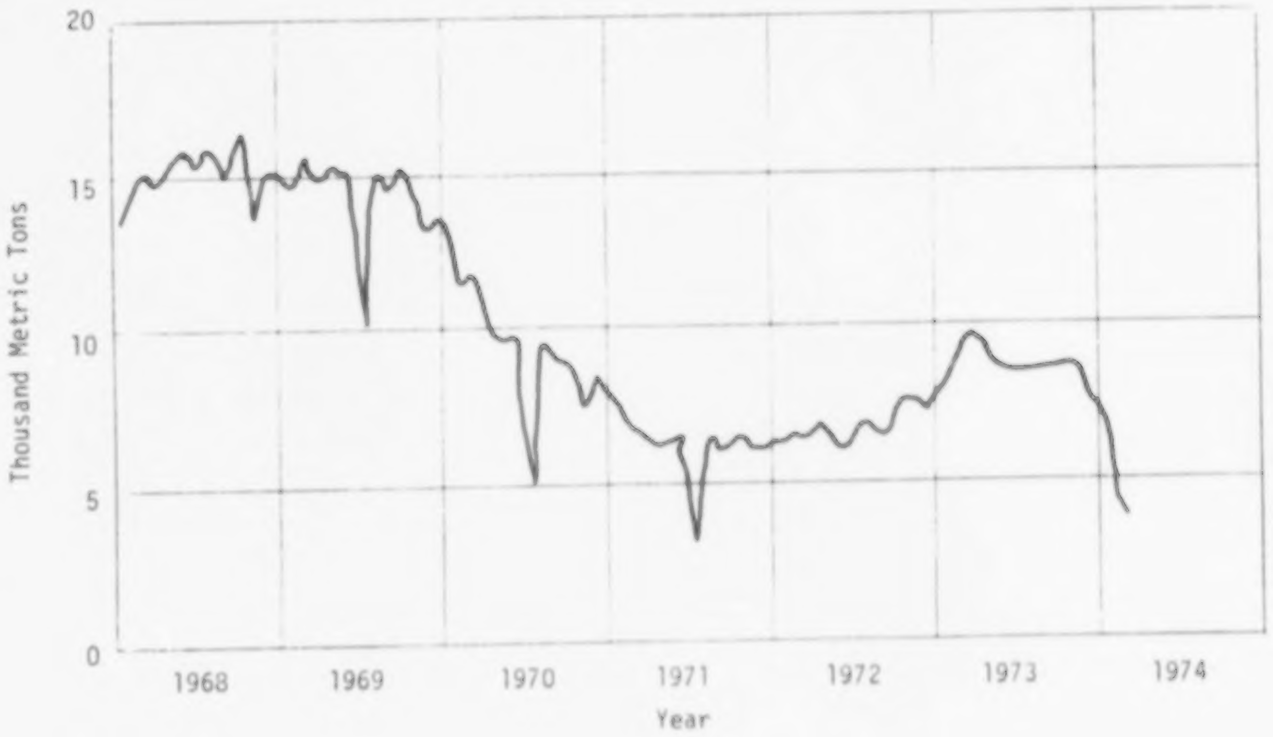

Figure 4-1. Monthly TNT Production at Joliet Army Ammunition Plant

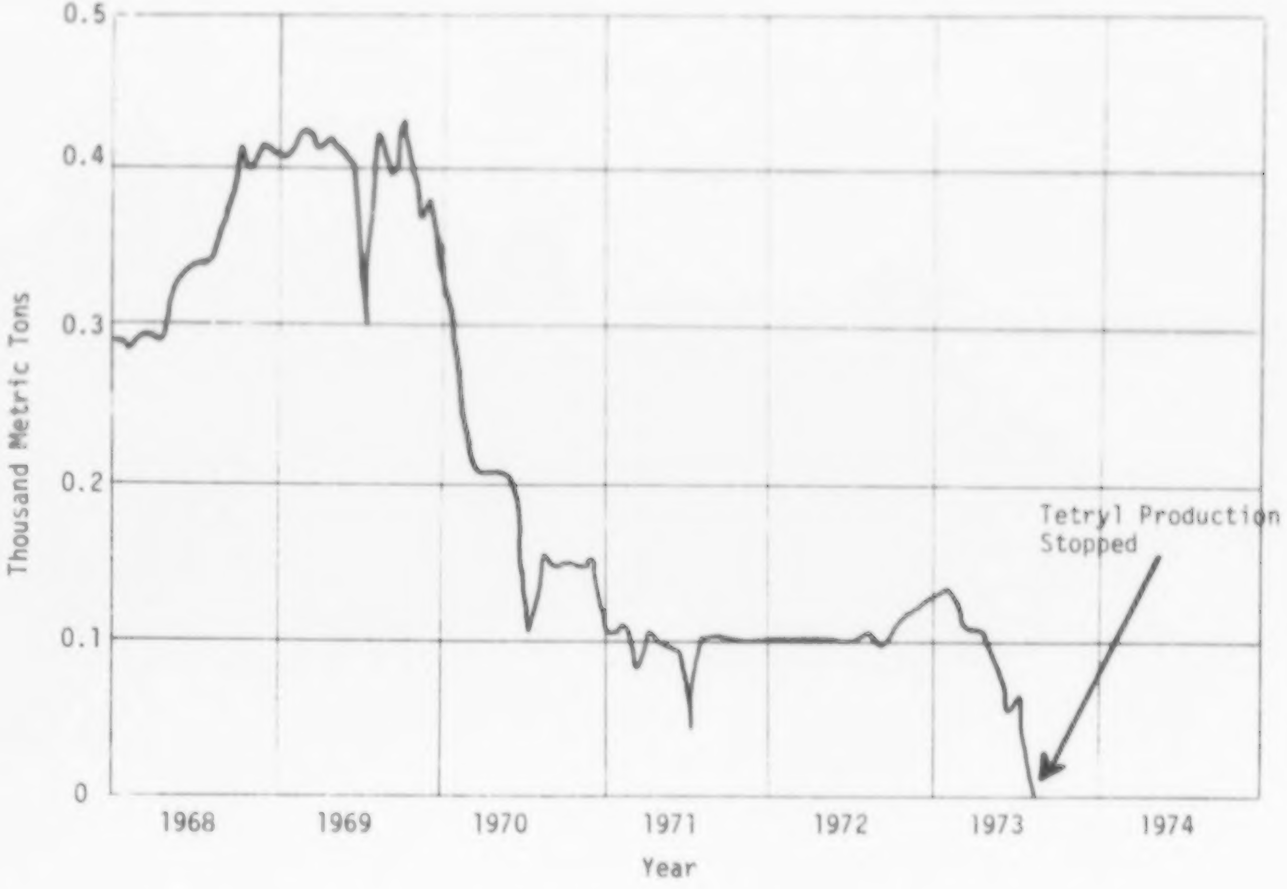

Figure 4-2. Monthly Tetryl Production at Joliet Army Ammunition Plant

5. WASTE CHARACTERIZATION

5.1 GENERAL

This section presents process flow diagrams and mass balances for typical plants of the organic chemicals, pesticides and explosives industries; short narrative descriptions of these typical plants and their hazardous waste streams; estimates of the quantities of land-destined hazardous wastes generated to land disposal by the industries in 1973; projections of the impact of air pollution control regulations and of the Federal Water Pollution Control Act Amendments on the industries' hazardous wastes destined for land disposal in 1977 and 1983; and listings of the highly dangerous waste stream components.

The process flow diagrams are schematic and have been deliberately chosen to represent a single-product process system — a typical "department" in the terminology used by many companies. This was done to simplify the process descriptions and the identification and characterization of hazardous waste streams. The norm for the industries, however, is a plant complex, composed of many departments, frequently interrelated, with interdependent feedstocks, intermediates, products and process waste streams. The process waste streams are often combined prior to treatment and disposal.

The quantities, compositions, and properties of the hazardous waste streams were determined, where possible, from the industry and government agency sources listed earlier in Table A-1, in the Appendix. Working process models were developed, based on the literature referenced, where such definitive data were absent.

The diagrams follow a uniform format. Feedstocks (raw materials) are on the reader's left; products are on the right. All quantities are based on unit weight of product. Miscellaneous water uses have not been included in the material balance. The use of process and cooling water varies so widely with location, climate, time of year, and specific equipment selection that presentation of data in a typical process flow diagram would be misleading.

5.2 ORGANIC CHEMICALS INDUSTRY

The major commercial products of the organic chemicals industry are almost 400 in number as indicated in Table 4-1. Of this total, approximately 100 are industrially significant — the 100 most important chemicals(19) with a manufacturing rate of approximately 23,000 metric tons (50 million pounds) or more per year. Twenty-one hypothetical typical plants, each using a single process, were selected on the basis of the significance of their products and process waste streams to characterize the organic chemicals industry. The selection had, as partial basis (with two exceptions*), the 23,000 metric ton or more per year production criterion for industrial significance. Consequently, all of the organic chemicals selected are products of the two major industry classifications (SIC 2865, cyclic crudes and intermediates and SIC 2869, industrial organic chemicals NEC) which represent the bulk of all organic chemical production. The products selected constituted approximately 9 percent by weight of the total 1973 production of the industry. The total process wastes (dry basis) discharged to land in 1973 by plants producing these products represented about 52 percent by weight of the total process wastes (dry basis) discharged to land by the industry. The processes were selected on the basis of generating significant quantities of land-destined wastes, and hence had a higher "waste discharge factor."

5.2.1 Typical Plant Process and Waste Stream Descriptions

It should be noted that no process flow diagram in this section represents an individual actual plant department or process line. The features presented represent a hypothetical typical case, and give a composite picture of usual operations in the single process selected to represent the manufacture of the product involved. Descriptions of these typical industrially significant processes are presented below.

Perchloroethylene SIC 28692(20, 21, 22, 23)

Production of perchloroethylene ("tetrachloroethylene") in 1973 totaled 320,000 metric tons (706 million pounds). There were eight major producers — Diamond Shamrock Corporation, Dow Chemical Company, E. I. duPont de

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*Benzoyl peroxide and the synthetic pyridines, which were selected as representatives of the important acyl peroxide (RC(O)OO(O)CR), and heterocyclic groups of chemical products, respectively.

Nemours and Company, Inc., Vulcan Materials Company (Chemical Division), Hooker Chemical Corporation (Division of Occidental Petroleum), PPG Industries, Inc., Stauffer Chemical Company (Industrial Division), and Ethyl Corporation. Typical plant sizes are in the range of 32,000 to 45,000 metric tons (50 to 100 million pounds) per year.

About 20 percent of the perchloroethylene manufactured uses chlorine and acetylene as starting materials. The chemistry of the reactions is as follows:

$$2Cl_2 + HC\equiv CH \xrightarrow[80^{o}C]{SbCl_3} C_2H_2Cl_4$$

$$C_2H_2Cl_4 \xrightarrow[300^{o}C]{\text{Catalyst}} Cl{-}CH{=}CCl_2 + HCl$$

$$ClCH{=}CCl_2 + Cl_2 \xrightarrow[70\text{-}80^{o}C]{FeCl_3} Cl_2CHCCl_3$$

$$2Cl_2CHCCl_3 + Ca(OH)_2 \xrightarrow{80^{o}C} 2Cl_2C{=}CCl_2 + CaCl_2 + 2H_2O$$

Chlorine and acetylene, each individually premixed with a reaction medium of recycled tetrachloroethane and antimony trichloride catalyst, are fed to a packed chlorination tower. The reaction product (Figure 5-1) is fed to a still and separated into spent antimony chloride catalyst, tetrachloroethane, and vent gas. The spent antimony trichloride catalyst is sent to recovery; overall catalyst loss is small$^{(24)}$ and estimated at 1 kg/1 million kg product.

The tetrachloroethane is split into a recycle stream, and a dehydrochlorinator feed stream. The dehydrochlorination of the tetrachloroethane takes place in a packed tower, filled with activated carbon catalyst, at 300^{o}C. The reaction products, trichloroethylene and hydrogen chloride are cooled and the liquid and gas phases are separated. The gaseous phase hydrogen chloride is absorbed in water and sold as commercial grade muriatic acid.

The condensate trichloroethylene is fed to a degasser and then to a distillation column for purification. The tails from the purification column constitute a "heavy ends" process waste stream. The combined heavy ends from this purification column and the perchloroethylene purification column are approximately 0.30 kg per kg product; they are sent to land disposal.

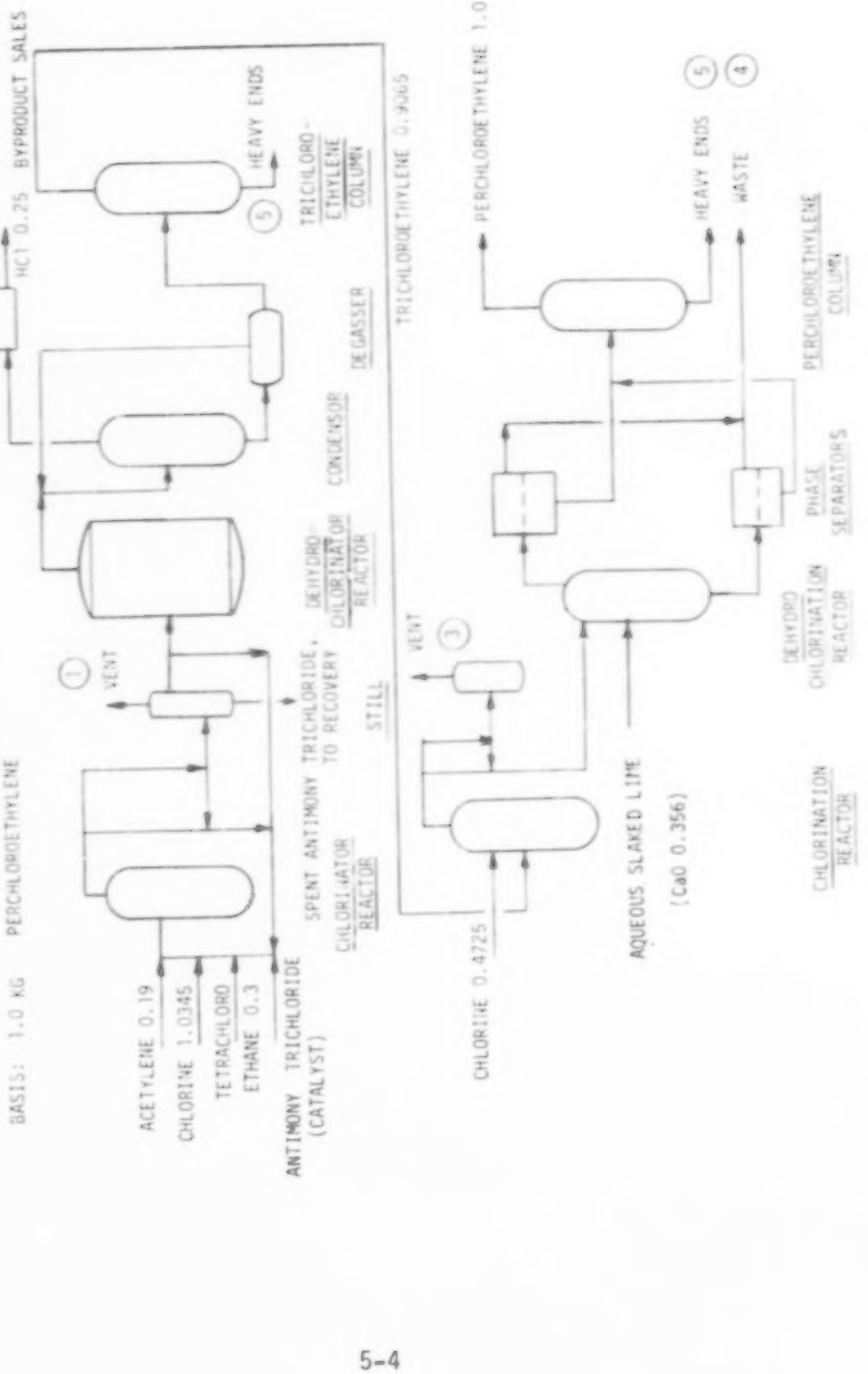
BASIS: 1.0 KG PERCHLOROETHYLENE
ACETYLENE 0.19
CHLORINE 1.0345
TETRACHLORO ETHANE 0.3
ANTIMONY TRICHLORIDE (CATALYST)
CHLORINATOR REACTOR
SPENT ANTIMONY TRICHLORIDE, TO RECOVERY
STILL
① VENT
DEHYDRO-CHLORINATOR REACTOR
CONDENSOR
DEGASSER
HCl RECOVERY
② TAIL GAS ABSORBER
HCl 0.25
BYPRODUCT SALES
⑤ HEAVY ENDS
TRICHLORO-ETHYLENE COLUMN
TRICHLOROETHYLENE 0.9065
CHLORINE 0.4725
VENT ③
AQUEOUS SLAKED LIME
(CaO 0.356)
CHLORINATION REACTOR
DEHYDRO CHLORINATION REACTOR
PHASE SEPARATORS
PERCHLOROETHYLENE COLUMN
PERCHLOROETHYLENE 1.0
HEAVY ENDS ⑤
WASTE ④

Figure 5-1. Perchloroethylene Manufacture

- PROCESS WASTE STREAMS

①
VENT ON REFLUX CONDENSER (GAS)
ETHANE 0.001135
METHANE 0.001135
TETRACHLOROETHANE 0.000453
↓
AIR

②
TAIL GAS ABSORBER (GAS)
HYDROGEN CHLORIDE 0.0009
TETRACHLOROETHANE 0.000453
TRICHLOROETHYLENE 0.0003175
TETRACHLOROETHYLENE 0.0009
↓
AIR

③
CHLORINATOR REACTOR REFLUX CONDENSER PURGE (GAS)
TRICHLOROETHYLENE 0.0028
PENTACHLOROETHANE 0.0003
DICHLOROETHANE 0.00235
↓
AIR

④
PHASE SEPARATORS AND WASTE LIQUOR STRIPPER ATTACHED TO DEHYDROCHLORINATOR (LIQUID)
CHLORINATED SOLVENTS - TRACE
CALCIUM HYDROXIDE 0.2405
CALCIUM CHLORIDE 0.3445
↓
WATER

⑤
HEAVY ENDS FROM PERCHLOROETHYLENE AND TRICHLOROETHYLENE COLUMNS (LIQUID-SOLID)
HEXACHLOROBUTADIENE 0.23
CHLOROBENZENES 0.02
CHLOROETHANES 0.01
CHLOROBUTADIENES 0.01
TARS AND RESIDUES 0.02
OTHER MATERIALS 0.01
↓
LAND

Figure 5-1. Perchloroethylene Manufacture (Continued)

The purified trichloroethylene is fed to a chlorination tower where chlorination to pentachloroethane takes place at 70° to 80°C in the presence of a ferric chloride catalyst. The product pentachloroethane is dehydrochlorinated, using aqueous slaked lime suspension, in a heated packed tower maintained at 80°C. The aqueous phase, containing unreacted slaked lime, calcium chloride and trace quantities of chlorinated solvents, is discharged, after separation from the perchloroethane, through an industrial outfall.

The crude perchloroethylene, after phase separation, is fed to a purification column. Product refined "perc" (perchloroethylene) is sent to storage. The column bottoms, or "heavy ends," are sent to land disposal. As noted earlier, the combined heavy ends from the trichloroethylene and perchloroethylene columns are about 0.30 kg per kg perchloroethylene product; analysis is about 77 percent hexachlorobutadiene, 7 percent chlorobenzenes, 7 percent tars and residues, 3 percent chloroethanes, and 3 percent chlorobutadienes. These heavy ends constitute a hazardous waste stream to land disposal; the constituents are bioaccumulative and are therefore classified as highly dangerous. Other losses of chlorinated hydrocarbons take place to the air at low levels from the reflux condensor (distillation column), the hydrochloric acid absorber, and the chlorination reaction reflux condensor. These losses total slightly less than 0.008 kg/kg product.

Nitrobenzene SIC 28651(20, 25, 26)

Nitrobenzene, classified as a "cyclic intermediate," was produced at the rate of 140,000 metric tons in 1973(4). The major producers reported were Allied Chemical Company,* American Cyanamid Company, E. I. duPont de Nemours and Company, Inc., First Chemical Corporation, Mobay Chemical Company, Monsanto Company, and Rubicon Chemicals Inc.(3) Typical plant capacities range from 4,500 metric tons (10 million pounds) to 38,000 metric tons (84 million pounds) per year.

The process employed is typical of many liquid phase organic nitration reactions. It is dependent upon the use of a large quantity of sulfuric acid to promote substitution rather than oxidation, to serve as a mutual solvent for the reactants, and to add to the heat-absorbing capability

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*No longer a manufacturer.

(heat capacity) of the reaction system. The mixed acid used for this reaction typically has the following composition: 50-60 percent H_2SO_4, 30-40 percent HNO_3, and about 8 percent water. The reaction which takes place is, typically:

$$C_6H_6 + HNO_3 \xrightarrow[H_2SO_4]{50^oC} C_6H_5NO_2 + H_2O$$

The overall production of nitrobenzene in a batch plant (Figure 5-2) is relatively simple. Benzene and mixed acid are fed in sequence to a jacketed, cooling coil-equipped, cast-iron or steel reaction kettle equipped with an efficient agitator. The time of reaction is temperature dependent and varies from 3 to 40 minutes(20). The temperature ranges (dependent upon process and company) from 45° to 95°C.

After completion of the reaction, the reaction mixture is separated into an upper (nitrobenzene) and a lower (spent acid) phase in a liquid/liquid separator.

The spent acid phase, diluted due to the water produced as a reaction product, is recycled and reused after concentration or regeneration. The nitrobenzene phase, after discharge from the separator, is washed with dilute sodium carbonate and purified by distillation. The washer wastes contain a small portion of nitrobenzene (0.00004 kg/kg product), sodium sulfate, and residual sodium carbonate. The purification column wastes contain nitrobody heavy ends (unknown nitro substituted aromatic compounds). They are considered highly dangerous on the basis of the generic physiological effects of nitro substituted aromatic compounds and this process waste stream is classified as a hazardous waste stream discharged to land. It is believed that the Federal Water Pollution Control Act Amendment will require the removal of the nitrobenzene currently discharged in washer waste water to industrial outfall.

1-Chloro-4-Nitrobenzene SIC 28651(24, 27)

Estimated production capacity for 1-chloro-4-nitrobenzene is approximately 52,000 metric tons (118 million pounds) per year. There were two major producers reported in 1972(3): E. I. duPont de Nemours and Company, Inc., and the Monsanto Company. Typical plant capacities are in tne 10,000 to 40,000 metric ton per year range. The product is basically an

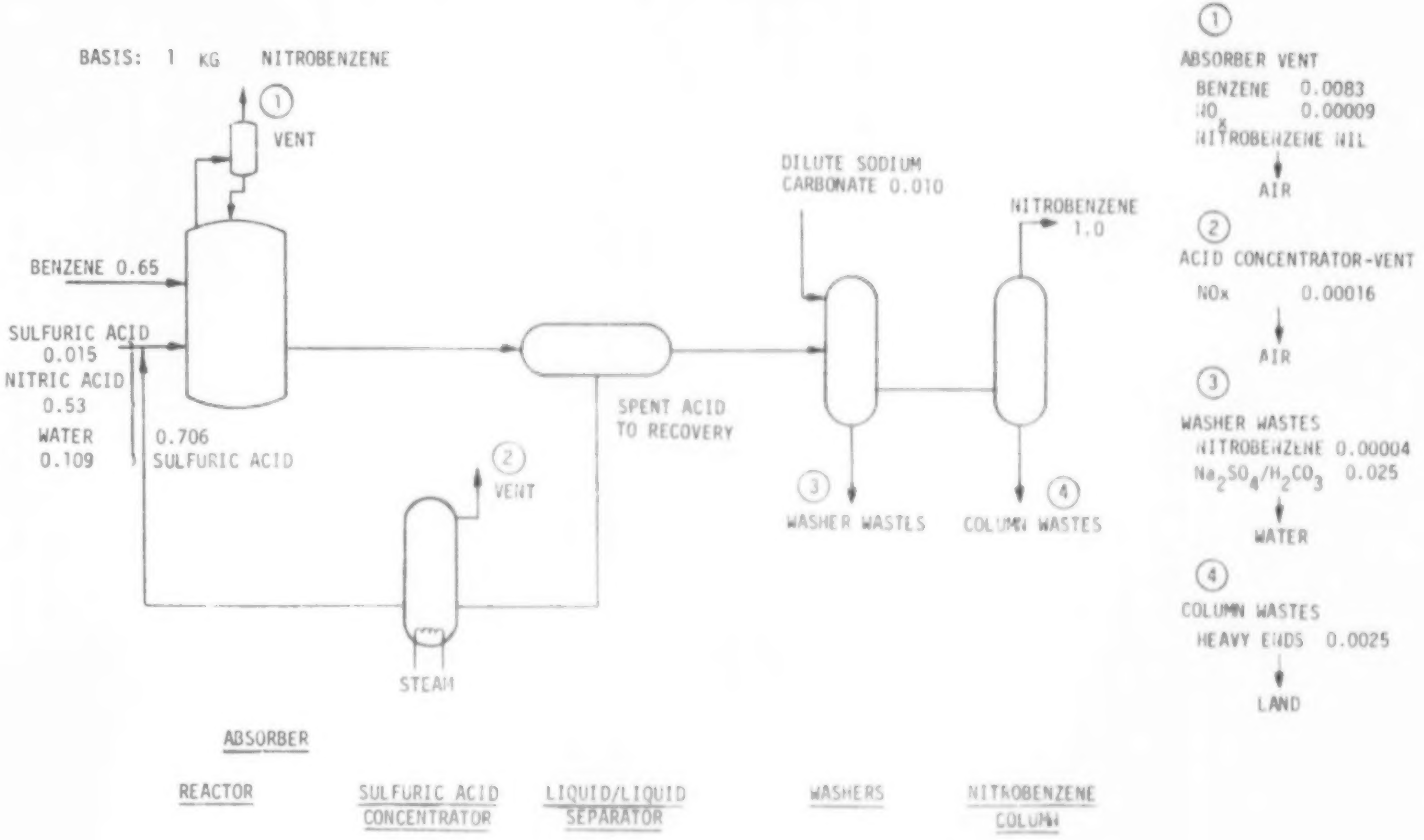
BASIS: 1 KG NITROBENZENE
①
VENT
BENZENE 0.65
SULFURIC ACID
0.015
NITRIC ACID
0.53
WATER
0.109
0.706
SULFURIC ACID
② VENT
STEAM
SPENT ACID
TO RECOVERY
DILUTE SODIUM
CARBONATE 0.010
NITROBENZENE
1.0
③ WASHER WASTES
COLUMN WASTES ④
ABSORBER
REACTOR
SULFURIC ACID CONCENTRATOR
LIQUID/LIQUID SEPARATOR
WASHERS
NITROBENZENE COLUMN
①
ABSORBER VENT
BENZENE 0.0083
NO_x 0.00009
NITROBENZENE NIL
AIR
②
ACID CONCENTRATOR-VENT
NOx 0.00016
AIR
③
WASHER WASTES
NITROBENZENE 0.00004
Na_2SO_4/H_2CO_3 0.025
WATER
④
COLUMN WASTES
HEAVY ENDS 0.0025
LAND

Figure 5-2. Nitrobenzene Manufacture

intermediate used for the manufacture of such chemicals as p-nitro-aniline, p-anisidine and 3,4-dichloro-1-nitro benzene; these are, in turn, used as intermediates in the manufacture of dyes, drugs, pesticides and photochemicals.

The reaction involves a simple nitration using sulfuric acid as the solvent for trichlorobenzene and the nitric acid. Two major competing reactions take place in the ratio shown:

$$C_6H_5Cl + HNO_3 \xrightarrow[40-70^{\circ}C]{H_2SO_4} \begin{cases} p - C_6H_4NO_2Cl + H_2O & \text{[illegible]}\% \\ o - C_6H_4NO_2Cl + H_2O & 34\% \end{cases}$$

Overall reaction yields are above 98 percent. The major cost element in the production of the desired para-isomer is separation from the ortho-isomer (which is recovered as a by-product, for other in-plant uses). Manufacture follows the flow diagram shown in Figure 5-3.

Chlorobenzene is reacted with mixed acid in a jacketed, agitated, cooling-coil equipped nitration kettle. Reaction takes place (in batch processes) over time intervals that range up to 9 hours. The charge is allowed to settle after reaction, and the spent acid layer is sent to the sulfuric acid plant for regeneration and rinse. The upper layer or mixture of crude chloronitrobenzenes, is washed with dilute sodium carbonate solution and vacuum dried. The mixture of chloronitrobenzenes is subjected to fractional crystallization and vacuum distillation to effect separation into ortho, meta and para (1,2-, 1,3-, and 1,4-) isomers . The tars and residues are concentrated in the residues from vacuum distillation for purification of the 1-chloro-2-nitrobenzene. These are composed of polyaromatic tars and unknown nitro substituted aromatic polymers (estimated at about 0.172 kg/kg of product 1-chloro-4-nitrobenzene). The polyaromatic tars and nitro substituted aromatic polymers are considered hazardous components on the basis of the physiological effects of these classes of material. This process waste stream is, therefore, considered a hazardous waste stream to land disposal, with moderately dangerous components.

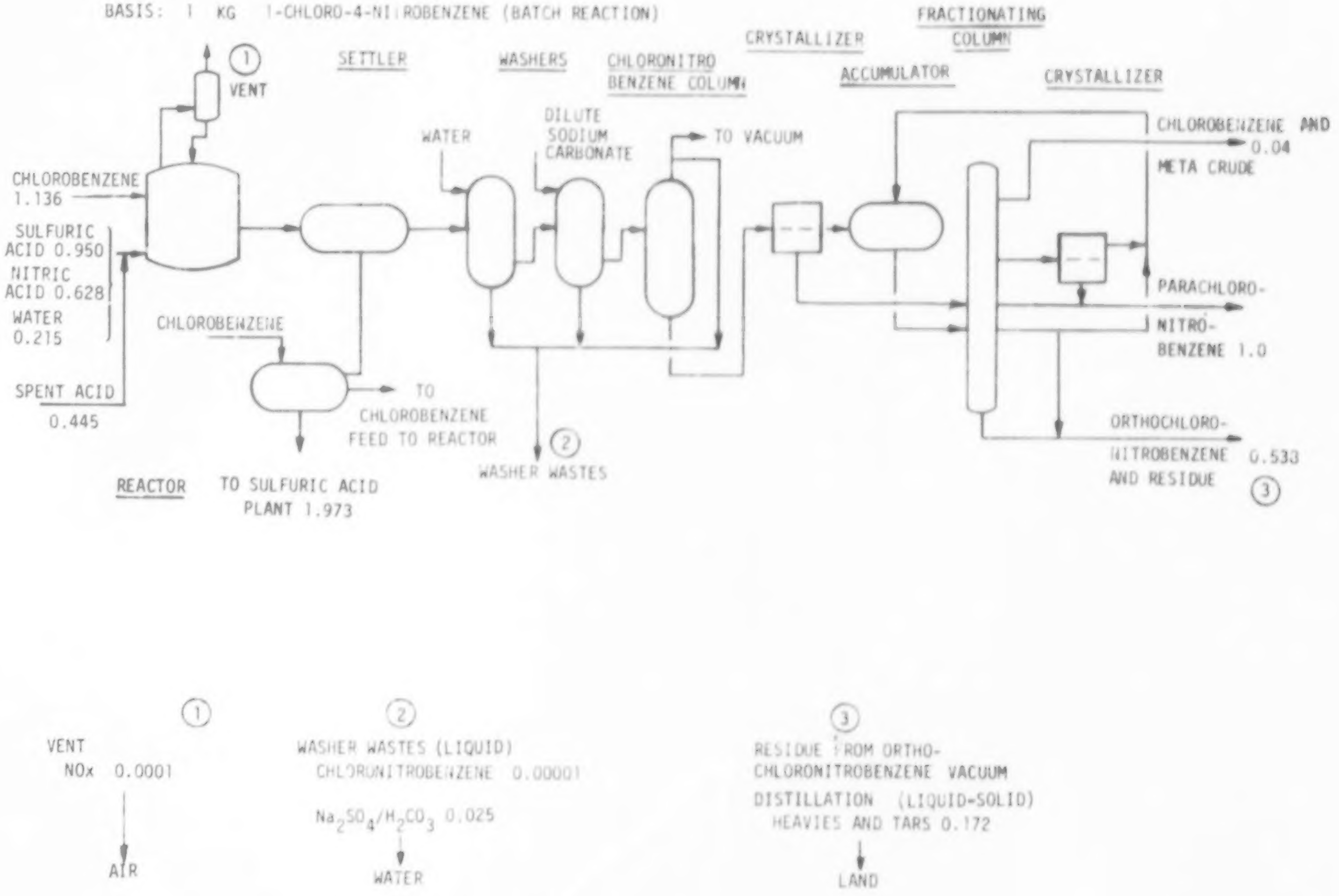
BASIS: 1 KG 1-CHLORO-4-NITROBENZENE (BATCH REACTION)
① VENT
SETTLER
WASHERS
CHLORONITRO BENZENE COLUMN
CRYSTALLIZER
FRACTIONATING COLUMN
ACCUMULATOR
CRYSTALLIZER
CHLOROBENZENE 1.136
SULFURIC ACID 0.950
NITRIC ACID 0.628
WATER 0.215
SPENT ACID 0.445
REACTOR
TO SULFURIC ACID PLANT 1.973
CHLOROBENZENE
TO CHLOROBENZENE FEED TO REACTOR
WATER
DILUTE SODIUM CARBONATE
TO VACUUM
② WASHER WASTES
CHLOROBENZENE AND META CRUDE 0.04
PARACHLORO-NITRO-BENZENE 1.0
ORTHOCHLORO-NITROBENZENE AND RESIDUE 0.533 ③
①
VENT
NOx 0.0001
AIR
②
WASHER WASTES (LIQUID)
CHLORONITROBENZENE 0.00001
Na2SO4/H2CO3 0.025
WATER
③
RESIDUE FROM ORTHO-CHLORONITROBENZENE VACUUM DISTILLATION (LIQUID-SOLID)
HEAVIES AND TARS 0.172
LAND

Figure 5-3. 1-Chloro-4-nitrobenzene Manufacture

Chlorinated Solvents (Chloromethanes) SIC 28692(21, 28)

United States total production for the chloromethanes in 1973 was as follows:(4)

Carbon tetrachloride	517,000 metric tons	(1,047 million pounds)
Chloroform	115,000 metric tons	(253 million pounds)
Methyl chloride	247,000 metric tons	(544 million pounds)
Dichloromethane	236,000 metric tons	(520 million pounds)

There were 12 major manufacturers reported(3): Allied Chemical, Continental Oil Company, Diamond Shamrock, Dow Corning Corporation, Dow Chemical Company, Vulcan Materials Company, FMC Corporation, E. I. duPont de Nemours and Company, Inc., PPG Industries, Inc., Stauffer Chemical Company, and Union Carbide Corporation. One typical plant has a production capacity of close to 50,000 metric tons per year of the various chloromethanes. The proportion of each produced is a function of sales demand. There are several major processes employed using chlorine, methane or methanol as feedstocks.

Figure 5-4 presents a flow diagram for a hypothetical typical plant using methanol and chlorine as raw materials. During start-up operation (not shown), the plant uses an external supply of HCl to react with methanol to produce methyl chloride. Subsequent to start-up, the plant generates the hydrogen chloride needed for the conversion of methanol to methyl chloride via the reaction of chlorine with methyl chloride and methyl chloride's chlorination products recycled from the various purification towers.

The reactions taking place concurrently in the thermal chlorination reactor are:

$$CH_3Cl + Cl_2 \longrightarrow CH_2Cl_2 + HCl$$

$$CH_2Cl_2 + Cl_2 \longrightarrow CHCl_3 + HCl$$

$$CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl$$

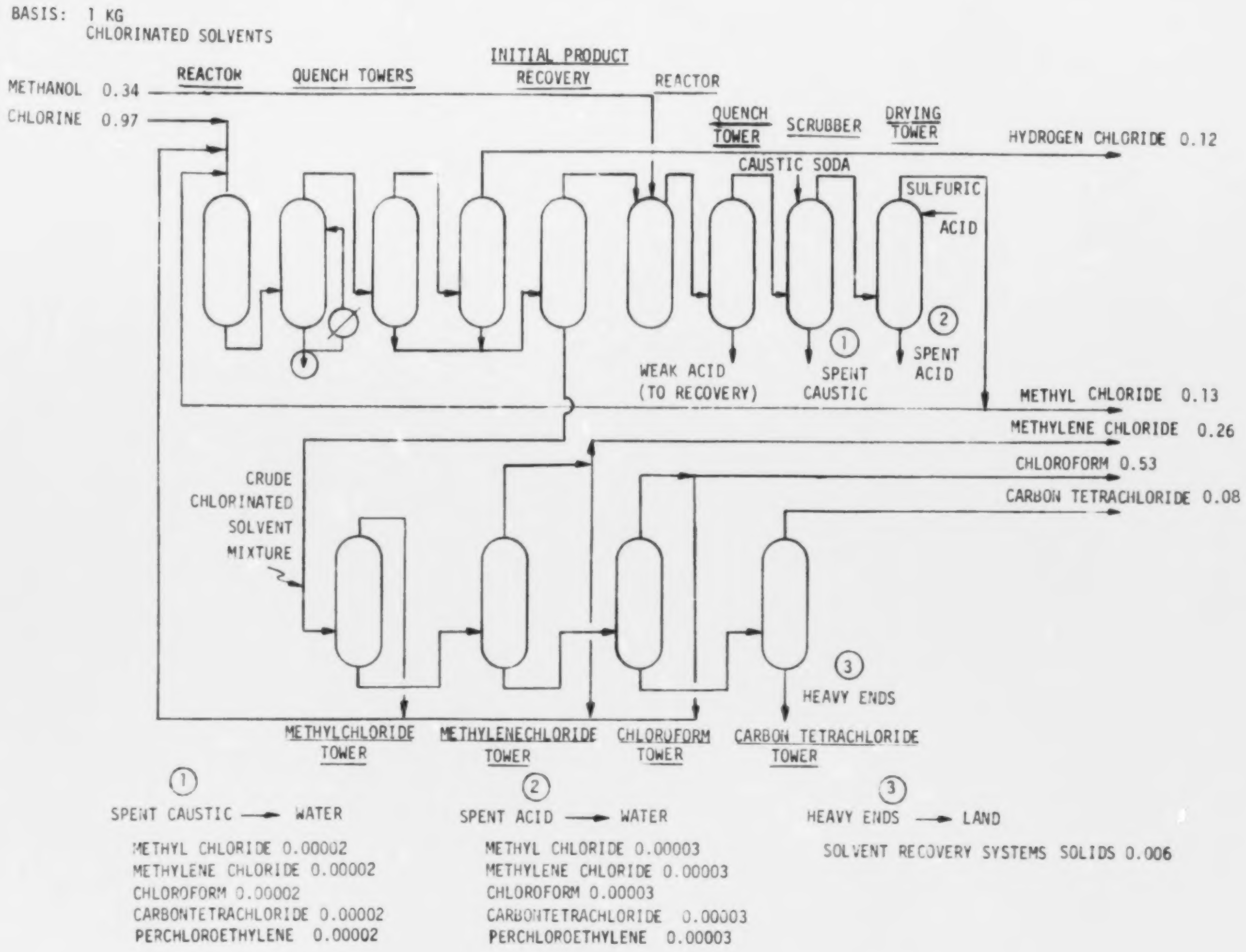
BASIS: 1 KG
CHLORINATED SOLVENTS
METHANOL 0.34
CHLORINE 0.97
REACTOR
QUENCH TOWERS
INITIAL PRODUCT RECOVERY
REACTOR
QUENCH TOWER
SCRUBBER
DRYING TOWER
CAUSTIC SODA
SULFURIC ACID
HYDROGEN CHLORIDE 0.12
WEAK ACID (TO RECOVERY)
① SPENT CAUSTIC
② SPENT ACID
METHYL CHLORIDE 0.13
METHYLENE CHLORIDE 0.26
CHLOROFORM 0.53
CARBON TETRACHLORIDE 0.08
CRUDE CHLORINATED SOLVENT MIXTURE
③ HEAVY ENDS
METHYLCHLORIDE TOWER
METHYLENECHLORIDE TOWER
CHLOROFORM TOWER
CARBON TETRACHLORIDE TOWER
①
SPENT CAUSTIC → WATER
METHYL CHLORIDE 0.00002
METHYLENE CHLORIDE 0.00002
CHLOROFORM 0.00002
CARBONTETRACHLORIDE 0.00002
PERCHLOROETHYLENE 0.00002
②
SPENT ACID → WATER
METHYL CHLORIDE 0.00003
METHYLENE CHLORIDE 0.00003
CHLOROFORM 0.00003
CARBONTETRACHLORIDE 0.00003
PERCHLOROETHYLENE 0.00003
③
HEAVY ENDS → LAND
SOLVENT RECOVERY SYSTEMS SOLIDS 0.006

Figure 5-4. Chlorinated Solvents Manufacture

The system produces an excess of hydrogen chloride over that required in the second reactor of Figure 5-4 to produce methyl chloride from methanol:

$$CH_3OH + HCl \xrightarrow[\text{Liquid Phase}]{\text{Catalyst}} CH_3Cl + H_2O$$

The excess hydrogen chloride is separated, dried, compressed and sold as anhydrous HCl.

The methyl chloride vapor phase produced in the second reactor is quenched, washed with caustic soda solution to remove traces of hydrogen chloride, and dried with sulfuric acid prior to transfer as liquid to product storage. The weak acid produced in the quench tower may be fortified with hydrogen chloride gas and sold as commercial hydrochloric acid. The spent caustic soda solution and spent sulfuric acid "bleeds" are neutralized and discharged through an industrial outfall.

The mixed chloromethane cuts from the thermal chlorination reactor, after separation of hydrogen chloride, are fractionated to recover the chlorinated hydrocarbon solvents. A portion of the methyl chloride, methylene chloride, and chloroform cuts from the fractionation towers is recycled. The remainder is sent to storage as product. The carbon tetrachloride after rectification goes to storage as product. The heavy ends, composed of higher chlorinated hydrocarbons (predominantly crude hexachlorobenzene and hexachlorobutadiene), are the distillation residues from the carbon tetrachloride tower. These wastes (0.006 kg/kg product) are sent to land disposal. Due to the toxicity of the hexachlorobenzene and hexachlorobutadiene (both rated as highly dangerous), the stream is considered to be a hazardous waste.

Chlorobenzene SIC 28651(24, 25, 29)

Monochlorobenzene production in the United States during 1973 was approximately 180,000 metric tons (397 million pounds)(4). The majority of this production was used as the starting material for other compounds. The major manufacturers reported(3) were Allied Chemical Corporation, Dow Chemical Company, Dover Chemical Corporation, Hooker Chemical Corporation, the Monsanto Company, Montrose Chemical Company, PPG Industries, Inc., and Standard Chlorine of Delaware, Inc. Both batch and continuous processes are employed, with conditions varied based on the percentages of mono- and di-chlorobenzenes required. A typical plant has a capacity of 32,000 metric tons (70 million pounds) per year.

Figure 5-5 presents a flow diagram for a hypothetical typical batch plant, selected as representative of older plants operating in 1973.* Iron turnings, retained in the glass-lined reaction kettle, are used to catalyze the reaction in the vessel between liquid phase dry benzene and gaseous chlorine, bubbled in at a rate which maintains a temperature of about 50°C. The product manufactured varies with the quantity of chlorine added to the reactors; for monochlorobenzene only, the chlorination is stopped when 60 percent of the theoretical chlorine requirements have been charged to the kettle.

The hydrogen chloride produced is scrubbed with benzene or chlorobenzene to remove entrained organics, and absorbed in water to produce commercial grade hydrochloric acid. The vent gas from the absorber/scrubber contains a low amount of residual HCl.

The product crude chlorobenzene from the reactor kettle is agitated in a steam-jacketed neutralizer with warm dilute (10 percent) sodium hydroxide solution to remove residual acidity. After neutralization, the chlorobenzene is settled in a separator. The bulk of the dichlorobenzenes settle out in a sludge which is sent to recovery by distillation. The supernatant liquor from the separator is distilled and separated into several fractions, which are in turn sent to batch fractionating towers for recovery of benzene, monochlorobenzene and dichlorobenzene. The distillation residues discharged from the fractionating columns contained about 0.044 kg of polychlorinated aromatic resinous materials per kilogram of monochlorobenzene product. These were discharged to land disposal. Because of the toxicity and bioaccumulation characteristics of the polychlorinated aromatic components, the waste stream is considered hazardous.

Ethyl Chloride SIC 28692 (22, 25, 27, 30)

Ethyl chloride production in the United States during 1973 totaled 299,000 metric tons (4). Of this quantity, approximately 128,000 metric tons were sold (4). Three-fourths of ethyl chloride production is normally

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*Proprietary information protection considerations and the nonavailability of data precluded the selection of the continuous process facility.

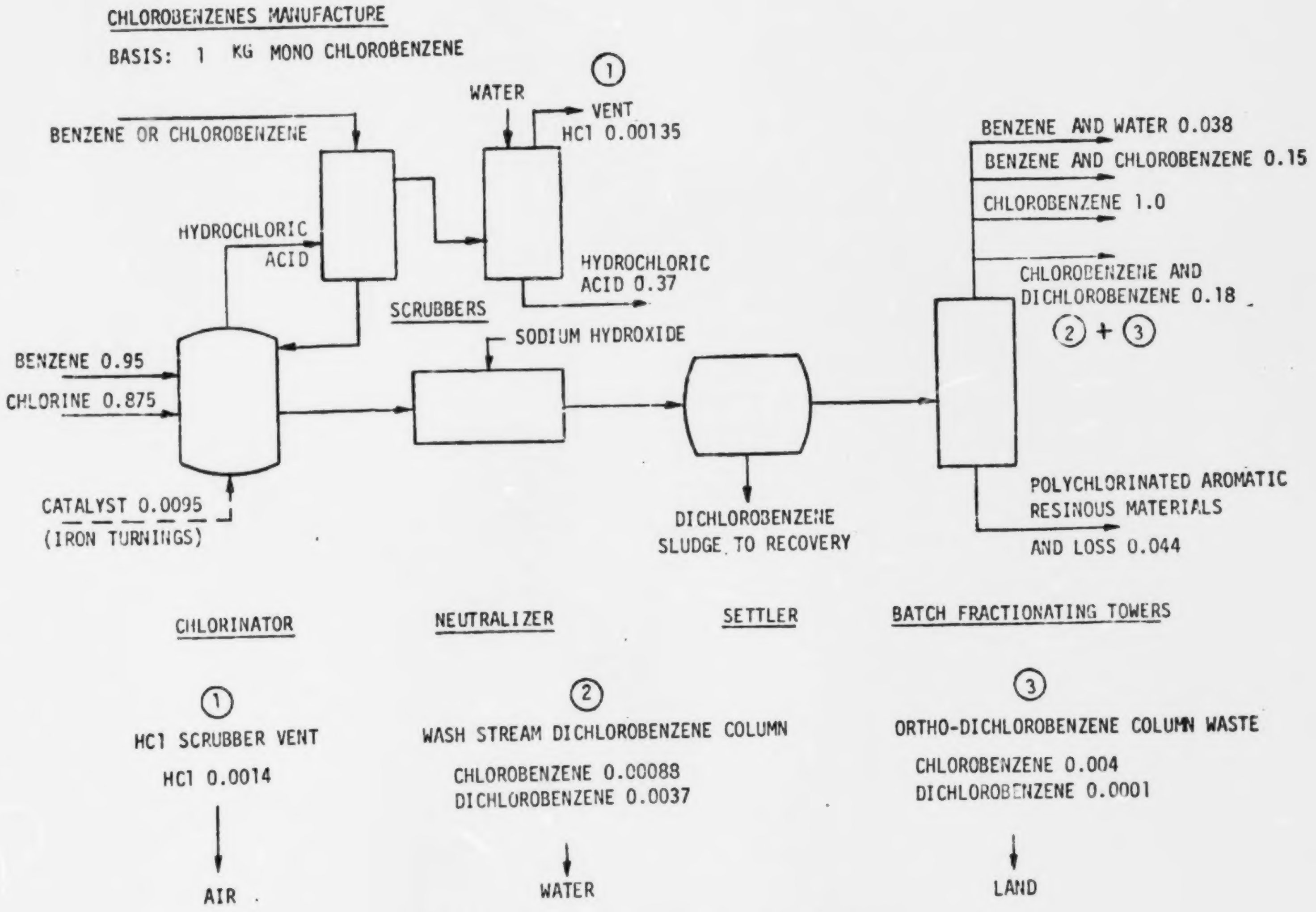

CHLOROBENZENES MANUFACTURE
BASIS: 1 KG MONO CHLOROBENZENE
BENZENE OR CHLOROBENZENE
WATER
①
VENT
HCl 0.00135
HYDROCHLORIC ACID
HYDROCHLORIC ACID 0.37
SCRUBBERS
SODIUM HYDROXIDE
BENZENE 0.95
CHLORINE 0.875
CATALYST 0.0095
(IRON TURNINGS)
DICHLOROBENZENE SLUDGE TO RECOVERY
BENZENE AND WATER 0.038
BENZENE AND CHLOROBENZENE 0.15
CHLOROBENZENE 1.0
CHLOROBENZENE AND DICHLOROBENZENE 0.18
② + ③
POLYCHLORINATED AROMATIC RESINOUS MATERIALS AND LOSS 0.044
CHLORINATOR
NEUTRALIZER
SETTLER
BATCH FRACTIONATING TOWERS
①
HCl SCRUBBER VENT
HCl 0.0014
AIR
②
WASH STREAM DICHLOROBENZENE COLUMN
CHLOROBENZENE 0.00088
DICHLOROBENZENE 0.0037
WATER
③
ORTHO-DICHLOROBENZENE COLUMN WASTE
CHLOROBENZENE 0.004
DICHLOROBENZENE 0.0001
LAND

Figure 5-5. Chlorobenzene Manufacture

used for the manufacture of tetra-ethyl lead(27). There are seven companies (American Chemical Corporation, Dow Chemical Company, E. I. duPont de Nemours and Company, Inc., Hercules, Inc., PPG Industries, Inc., Shell Chemical Company Division of Shell Oil Company, and Ethyl Corporation)(4) listed as major manufacturers. A typical process line size is 90,000 metric tons (200 million pounds) of ethyl chloride production per year.

A continuous hydrochlorination process (presented in Figure 5-6) accounted for about 88 percent of production(27, 30) in 1973. Anhydrous hydrogen chloride, in the presence of aluminum chloride, reacts with ethylene in both liquid and vapor phases to give 90 to 95 percent yields of ethyl chloride(22, 30). The yield of polychloro compounds is reduced by the addition of ethylene dichloride to the reaction mixture(30). The chemistry of the reaction is:

$$C_2H_4 + HCl \xrightarrow[35\text{-}40^{\circ}C]{AlCl_3} C_2H_5Cl$$

In addition to ethyl chloride, the reaction produces a hydropolymer oil by-product (0.02 kg per kg of ethyl chloride) from the separator, chlorinated hydrocarbon tails (0.093 kg per kg of ethyl chloride) from the fractionating column, and spent catalyst from the reactor. The spent catalyst is regenerated and recycled. The by-product hydropolymer oil is sold. The fractionating column tails are sent to chlorinated solvent manufacture; they are composed of 3 percent ethyl chloride, 22 percent dichloroethanes, 32 percent trichloroethylene, and 43 percent heavy chlorinated organics.

While there are, apparently, no process wastes sent directly to land disposal as a result of ethyl chloride production, a process waste is sent to land disposal from the chlorinated solvent production facility associated with ethyl chloride production. The "heavy chlorinated organics" portion of the fractionating column wastes sent to the plant site's chlorinated solvent process line is discharged as a part of the solvent process line distillation residues sent to land disposal.(22) These distillation residues are mixed heavy chlorinated hydrocarbons (77 percent hexachlorobutadiene, 7 percent chlorobenzenes, 3 percent chloroethanes, 3 percent chlorobutadienes, 7 percent tars and residues). These wastes constitute a hazardous waste stream because of the toxicity and bioaccumulability of the hexachlorobutadiene, chlorobenzene, and chloroethane components.

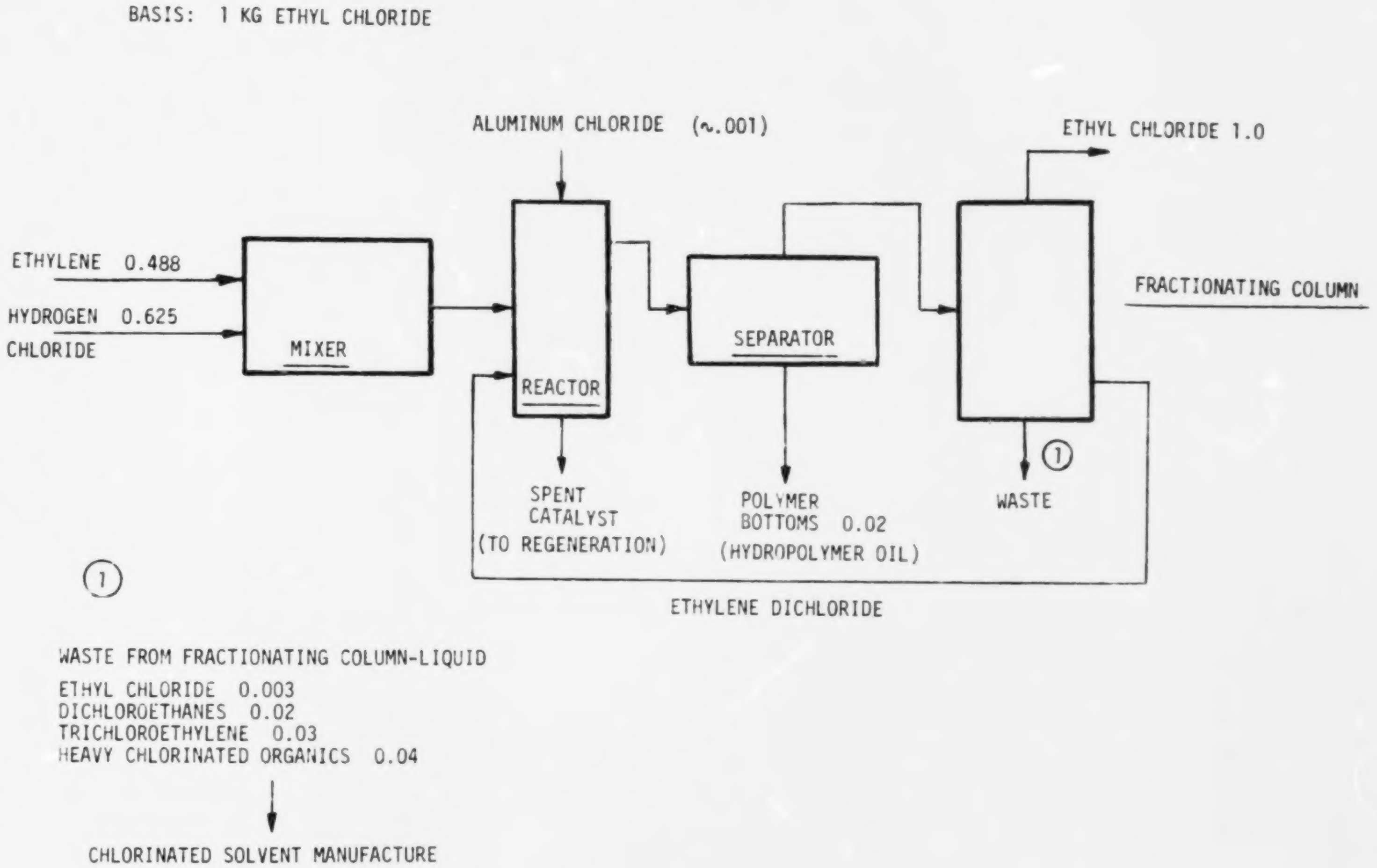

BASIS: 1 KG ETHYL CHLORIDE
ALUMINUM CHLORIDE (~.001)
ETHYL CHLORIDE 1.0
ETHYLENE 0.488
HYDROGEN 0.625
CHLORIDE
MIXER
REACTOR
SEPARATOR
FRACTIONATING COLUMN
SPENT
CATALYST
(TO REGENERATION)
POLYMER
BOTTOMS 0.02
(HYDROPOLYMER OIL)
①
WASTE
ETHYLENE DICHLORIDE
①
WASTE FROM FRACTIONATING COLUMN-LIQUID
ETHYL CHLORIDE 0.003
DICHLOROETHANES 0.02
TRICHLOROETHYLENE 0.03
HEAVY CHLORINATED ORGANICS 0.04
CHLORINATED SOLVENT MANUFACTURE

Figure 5-6. Ethyl Chloride Manufacture

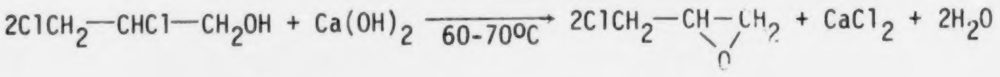
Epichlorohydrin SIC 28692(20, 25, 31)

Estimated 1974 active capacity for the production of epichlorohydrin (1-chloro-2,3-epoxy propane) was 225,000 metric tons (495 million pounds) per year. Major uses of epichlorohydrin include the manufacture of epoxy resins and glycerin manufacture. There were two active producers reported(3): Dow Chemical Company and Shell Chemical Company (a division of Shell Oil Company). Plant sizes ranged from 27,000 to 125,000 metric tons per year for the three producing plants. The typical plant size selected was 75,000 metric tons per year.

The major process used for the manufacture of epichlorohydrin is shown in Figure 5-7. Allyl chloride, chlorine, and slaked lime are the major raw materials. Yields based on allyl chloride consumption are between 85 and 90 percent. There are two steps in the chemistry of the process. The first is chlorohydroxylation of allyl chloride to dichlorohydrin:

$$\mathrm{ClCH_2{-}CH{=}CH_2 + HOCl \xrightarrow[30\text{-}40^{\circ}C]{} ClCH_2{-}CHCl{-}CH_2OH}$$

The second reaction is the conversion of dichlorohydrin to epichlorohydrin (dehydrochlorination and epoxide formation):



$$\mathrm{2ClCH_2{-}CHCl{-}CH_2OH + Ca(OH)_2 \xrightarrow[60\text{-}70^{\circ}C]{} 2ClCH_2{-}\underbrace{CH{-}CH_2}_{O} + CaCl_2 + 2H_2O}$$

Allyl chloride is fed continuously to a stirred tank where it reacts at atmospheric pressure at 30-40°C in the liquid phase with a solution of hypochlorous acid. The hypochlorous acid is produced in a packed tower by dissolving chlorine in water. The reaction tank effluent is fed to a separator; the upper layer (aqueous phase) is recycled to the hypochlorous acid tower. The underflow, chiefly dichlorohydrins, is fed to the second agitated reactor, where virtually quantitative conversion to epichlorohydrin by reaction with lime slurry takes place. Trichloropropane is used as a solvent for the epichlorohydrin. The effluent from the second reactor is steam stripped, removing epichlorohydrin as the water azeotrope. The undercut (calcium chloride solution, and the excess lime, in suspension) is sent to by-product recovery, or discharged through an industrial outfall. The distillate's water and organic phases are separated, with the undercut fed to a fractionating tower for recovery of epichlorohydrin and solvent. The

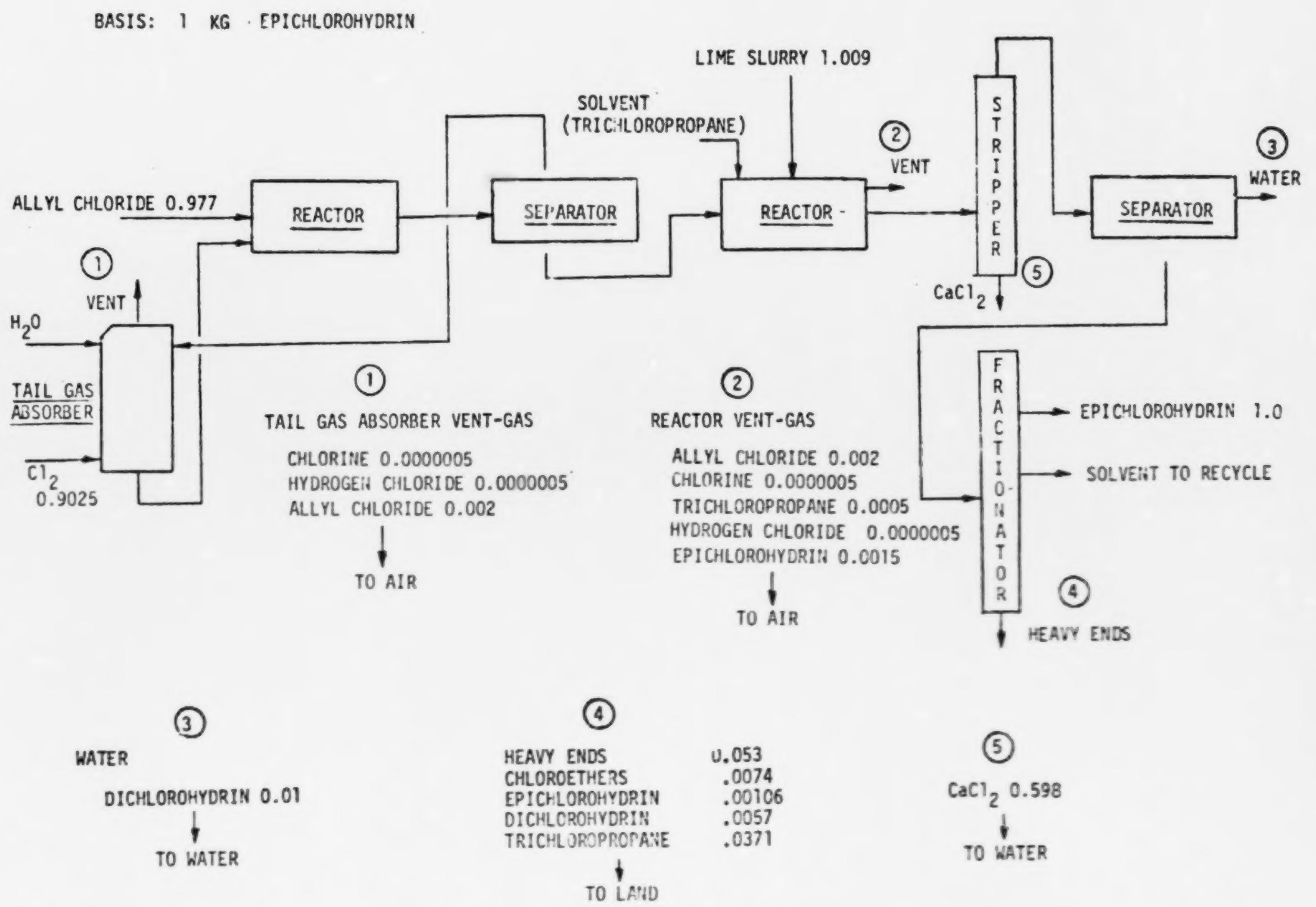

BASIS: 1 KG EPICHLOROHYDRIN
ALLYL CHLORIDE 0.977
REACTOR
SEPARATOR
SOLVENT (TRICHLOROPROPANE)
LIME SLURRY 1.009
REACTOR
② VENT
STRIPPER
⑤
$CaCl_2$
SEPARATOR
③ WATER
① VENT
H_2O
TAIL GAS ABSORBER
Cl_2 0.9025
FRACTIONATOR
EPICHLOROHYDRIN 1.0
SOLVENT TO RECYCLE
④ HEAVY ENDS
① TAIL GAS ABSORBER VENT-GAS
CHLORINE 0.0000005
HYDROGEN CHLORIDE 0.0000005
ALLYL CHLORIDE 0.002
TO AIR
② REACTOR VENT-GAS
ALLYL CHLORIDE 0.002
CHLORINE 0.0000005
TRICHLOROPROPANE 0.0005
HYDROGEN CHLORIDE 0.0000005
EPICHLOROHYDRIN 0.0015
TO AIR
③ WATER
DICHLOROHYDRIN 0.01
TO WATER
④
HEAVY ENDS 0.053
CHLOROETHERS .0074
EPICHLOROHYDRIN .00106
DICHLOROHYDRIN .0057
TRICHLOROPROPANE .0371
TO LAND
⑤ $CaCl_2$ 0.598
TO WATER

Figure 5-7. Epichlorohydrin Manufacture

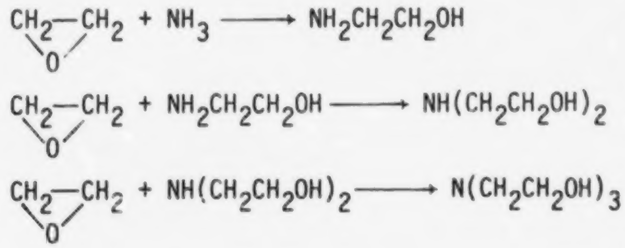
purified epichlorohydrin cut is sent to storage. The recovered solvent is recycled.

The small amount of dichlorohydrins carried over from the steam stripper in the epichlorohydrin-water azeotrope is largely discharged in the water phase from the second separator. The heavy ends discharged as still bottoms from the fractionator contain some epichlorohydrin, 10 percent dichloropropanol, 14 percent chloroethers, and 70 percent trichloropropane in the 0.053 kg/kg product discharged to land. The heavy ends constitute a hazardous waste discharge to land disposal; the constituents are currently rated as moderately dangerous.

Ethanolamines SIC 28692(21, 25)

The three ethanolamines – mono-, di-, and triethanolamine – had a total reported 1973 production(4) of 133,000 metric tons (293 million pounds). Monoethanolamine (MEA) production was 40,000 metric tons. The major manufacturers of MEA were Dow Chemical Company, Glyco Chemicals Incorporated, Jefferson Chemical Company, Koch Chemical Company, Olin Corporation, and Union Carbide Corporation; with the exception of Glyco Chemicals Incorporated these companies were also major manufacturers of diethanolamine (DEA) and triethanolamine (TEA). DEA production in 1973 was 48,000 metric tons; TEA production for the same year was 45,000 metric tons. A typical plant size is 14,000 metric tons per year.

The ethanolamines are made by reacting ethylene oxide and excess ammonia. Yields are generally of the order of 80 percent, based on ethylene oxide conversion to ethanolamines. A hypothetical typical plant flow diagram is presented in Figure 5-8. Ethylene oxide, aqueous ammonia solution, and recycled amines are fed continuously to a reactor. Ammonolysis of the ethylene oxide takes place exothermally. The ratio of MEA, DEA and TEA formed is dependent upon the ratio of the reactants. The reactions taking place concurrently are:



$$\underset{O}{CH_2-CH_2} + NH_3 \longrightarrow NH_2CH_2CH_2OH \qquad \text{MEA}$$

$$\underset{O}{CH_2-CH_2} + NH_2CH_2CH_2OH \longrightarrow NH(CH_2CH_2OH)_2 \qquad \text{DEA}$$

$$\underset{O}{CH_2-CH_2} + NH(CH_2CH_2OH)_2 \longrightarrow N(CH_2CH_2OH)_3 \qquad \text{TEA}$$

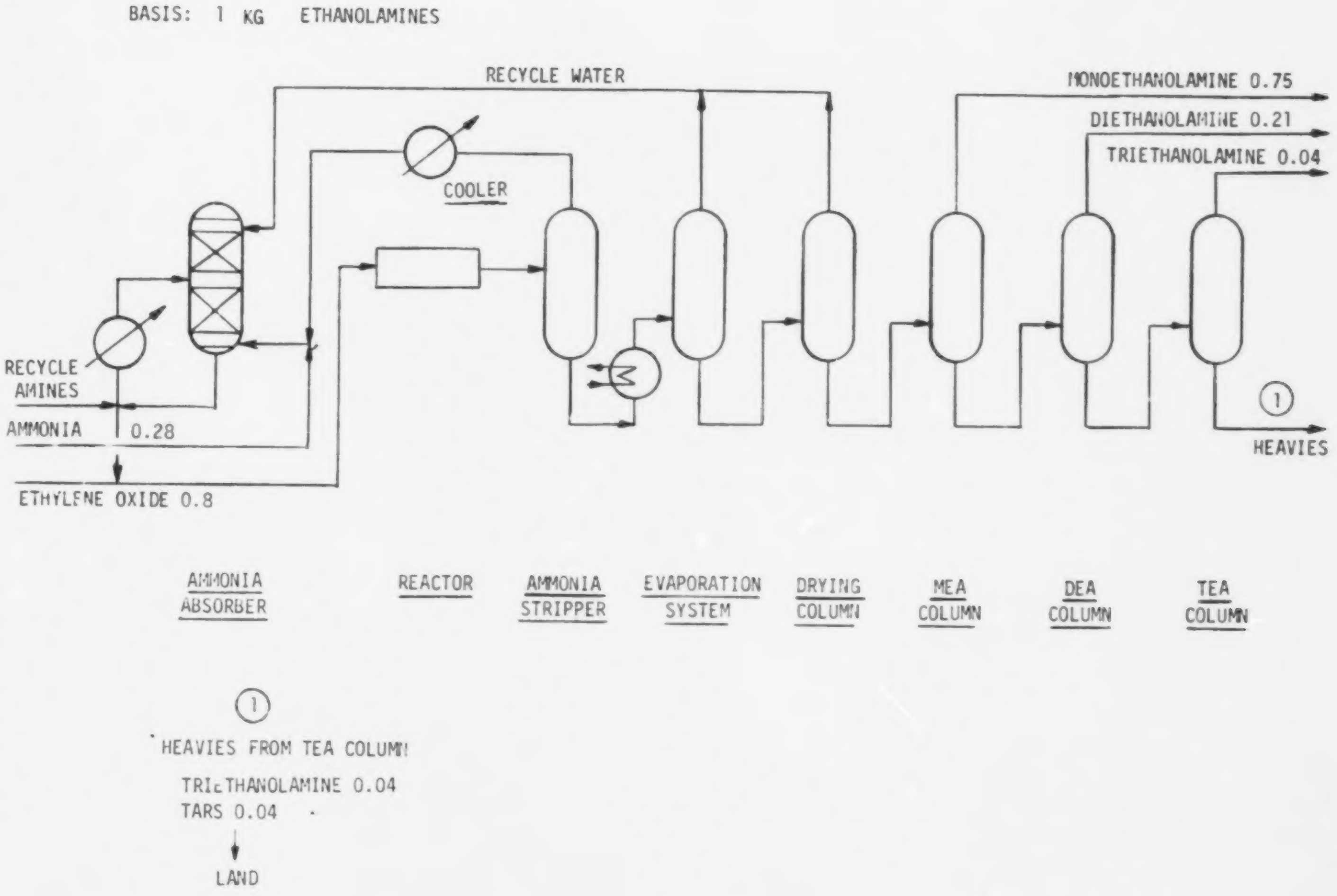

BASIS: 1 KG ETHANOLAMINES
RECYCLE WATER
COOLER
RECYCLE AMINES
AMMONIA
0.28
ETHYLENE OXIDE 0.8
MONOETHANOLAMINE 0.75
DIETHANOLAMINE 0.21
TRIETHANOLAMINE 0.04
①
HEAVIES
AMMONIA ABSORBER
REACTOR
AMMONIA STRIPPER
EVAPORATION SYSTEM
DRYING COLUMN
MEA COLUMN
DEA COLUMN
TEA COLUMN
①
HEAVIES FROM TEA COLUMN
TRIETHANOLAMINE 0.04
TARS 0.04
LAND

Figure 5-8. Ethanolamines Manufacture

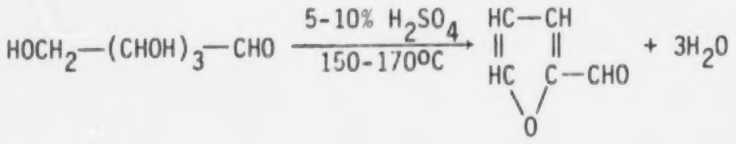
The reactor effluent is stripped of its excess ammonia in the ammonia stripper. The overhead (excess ammonia) from the stripper, plus make-up ammonia, is fed to an absorber for the production of the aqueous ammonia fed to the reactor.

The ethanolamines are recovered from the bottoms of the ammonia stripper by evaporation of the water, followed by drying in a drying column. The water evaporated is condensed and used as feed to the ammonia absorber. The dried ethanolamines are fractionated in a product distillation train to produce recycle amines, product MEA, DEA, and TEA, and rejected high boiling distillation residues.

The rejected distillation residues from the TEA column are estimated to be 0.08 kg per kg of product, and contain equal amounts of TEA and tars of unknown composition. The distillation residues are considered a hazardous waste stream due to their moderately dangerous amine and tar components, and are discharged to land disposal.

Furfural SIC 28692(4, 24)

Furfural (2-furaldehyde) currently has only one major manufacturer (the Quaker Oats Company)(4). Capacity for furfural in 1974 was estimated as 68,000 metric tons per year(11). Typical plant capacity is estimated at 35,000 metric tons per year. The production of furfural, as presented in Figure 5-9, is dependent upon the hydrolysis of the pentosans present in corncobs, rice hulls, cottonseed bran, and oat hulls. The reaction, with xylose as an example, is as follows:



The reaction is carried out, batchwise, in rotating digesters, under steam pressures of 4.5 - 7.9 x 10^3 newton/meter^2 (50-100 psig) for approximately 2 hours. The steam distilled furfural is further purified by fractional distillation. Methanol is produced and sold as a by-product. The stripped hulls are burned as an energy source or sold as a by-product for use as a fertilizer conditioner. Wastes to land include still bottoms (0.5 kg tars and polymers/kg furfural and 0.06 kg sulfuric acid/kg furfural) and filter

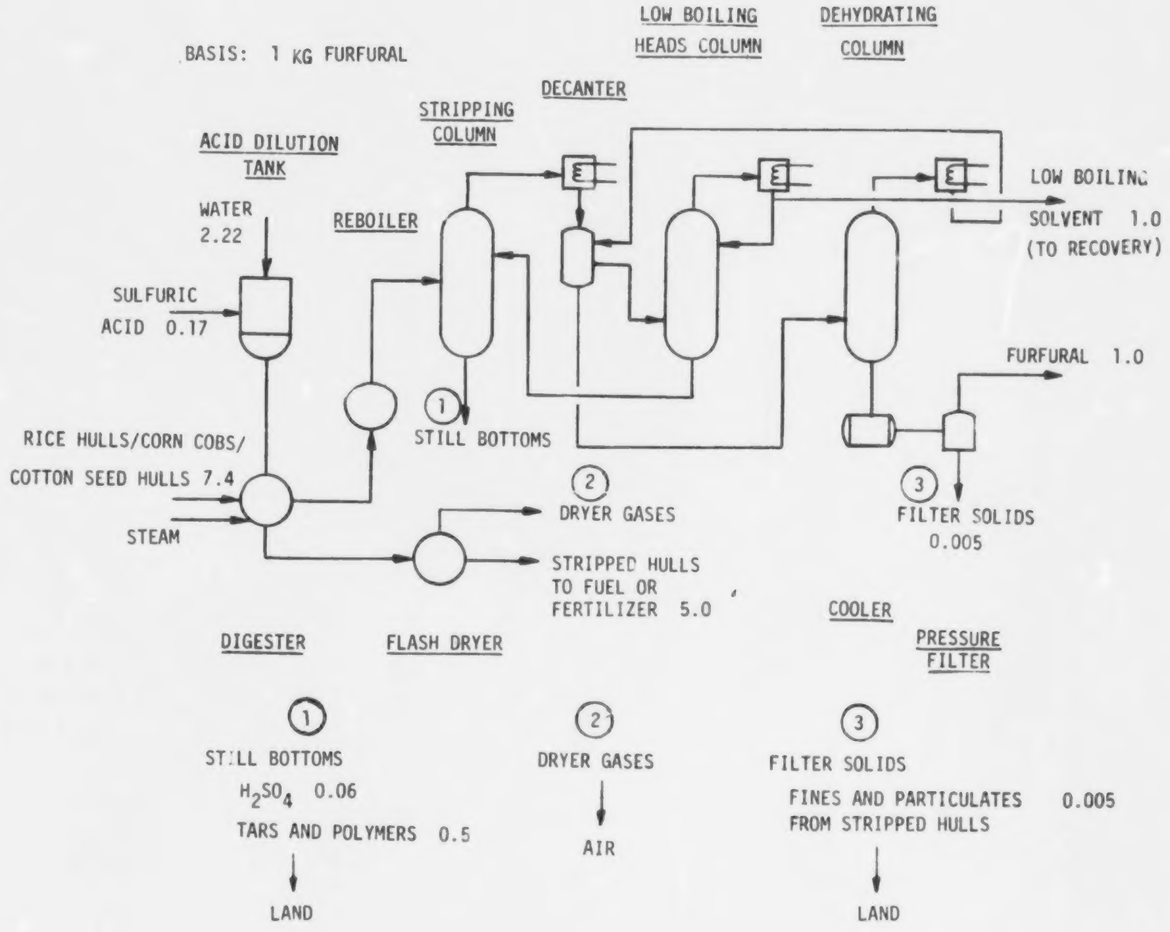

BASIS: 1 KG FURFURAL
LOW BOILING HEADS COLUMN
DEHYDRATING COLUMN
DECANTER
STRIPPING COLUMN
ACID DILUTION TANK
WATER 2.22
REBOILER
SULFURIC ACID 0.17
LOW BOILINC SOLVENT 1.0 (TO RECOVERY)
FURFURAL 1.0
RICE HULLS/CORN COBS/ COTTON SEED HULLS 7.4
STEAM
① STILL BOTTOMS
② DRYER GASES
STRIPPED HULLS TO FUEL OR FERTILIZER 5.0
③ FILTER SOLIDS 0.005
COOLER
PRESSURE FILTER
DIGESTER
FLASH DRYER
① ST:LL BOTTOMS
H_2SO_4 0.06
TARS AND POLYMERS 0.5
LAND
② DRYER GASES
AIR
③ FILTER SOLIDS
FINES AND PARTICULATES FROM STRIPPED HULLS 0.005
LAND

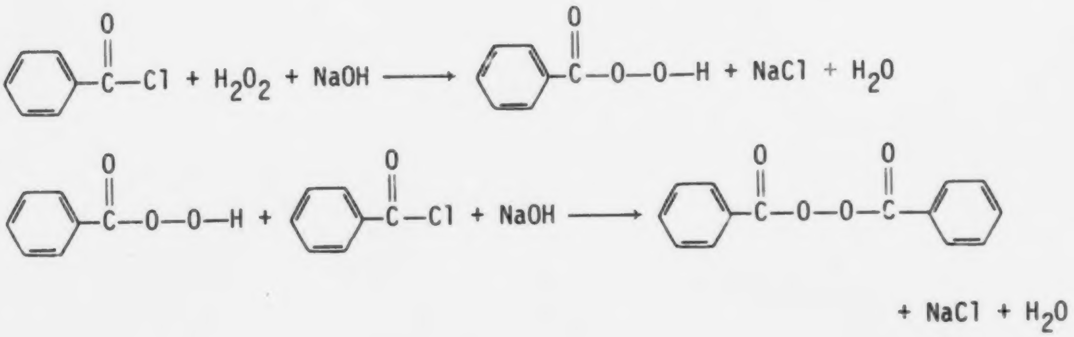
Figure 5-9. Furfural Manufacture

solids (0.005 kg fines and particulates from stripped hulls/kg furfural). The tars and polymers, because of their furfural content, are presumed to be a hazardous waste.

Benzoyl Peroxide SIC 28691(32, 33)

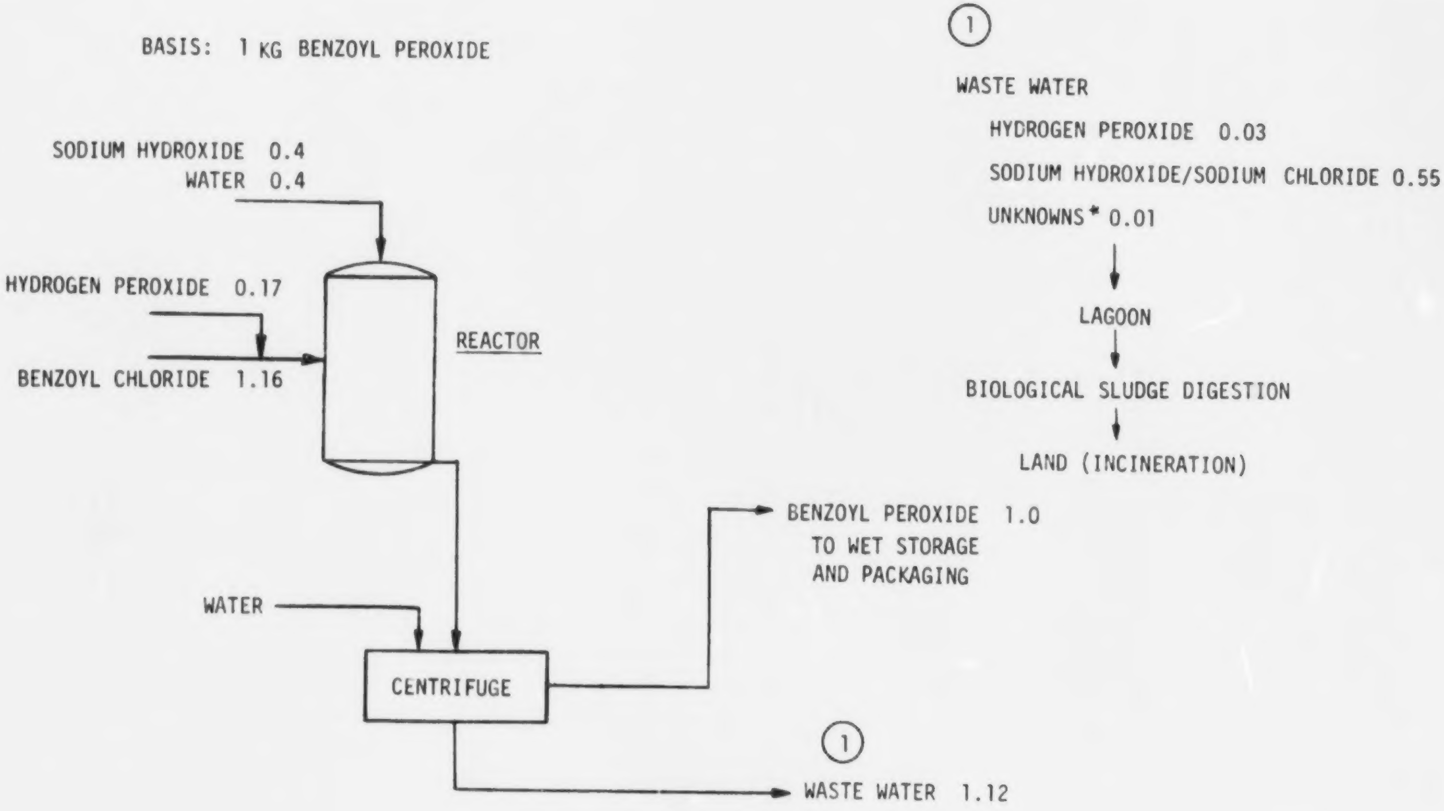
Benzoyl peroxide was for a long period of time the most important industrial aromatic diacyl peroxide. Production in 1973 was 4,000 metric tons(4). Manufacturers included Dart Industries (Aztec Chemicals Division), Noury Chemical Corporation, Norac Company, Inc. (Mathe Chemical Company Division), Reichhold Chemicals Inc., Witco Chemical Company, Inc., and Pennwalt Corporation (Lucidol Division). Typical plant capacities are estimated to range from 500 metric tons (1.1 million pounds) to 2,000 metric tons (4.4 million pounds) per year. The product has been known to be explosive when subject to fire/thermal shock.

Benzoyl peroxide (Figure 5-10) is produced by the step condensation of benzoyl chloride with hydrogen peroxide to yield perbenzoic acid, which reacts further with benzoyl chloride to yield benzoyl peroxide. The hydrogen chloride formed is continuously removed by in-situ reaction with 50 percent sodium hydroxide solution, shifting the equilibrium in favor of the benzoyl peroxide. The reactions are:



The product is removed by centrifuging and is washed, stored wet, or packaged after drying.

The major waste stream is wastewater which includes backwash, and is lagooned, skimmed, and sent to water treatment. The excess sodium hydroxide (0.07 kg/kg product) and the sodium chloride reaction product (0.48 kg/kg


BASIS: 1 KG BENZOYL PEROXIDE
SODIUM HYDROXIDE 0.4
WATER 0.4
HYDROGEN PEROXIDE 0.17
BENZOYL CHLORIDE 1.16
REACTOR
WATER
CENTRIFUGE
BENZOYL PEROXIDE 1.0
TO WET STORAGE
AND PACKAGING
①
WASTE WATER 1.12
①
WASTE WATER
HYDROGEN PEROXIDE 0.03
SODIUM HYDROXIDE/SODIUM CHLORIDE 0.55
UNKNOWNS* 0.01
LAGOON
BIOLOGICAL SLUDGE DIGESTION
LAND (INCINERATION)

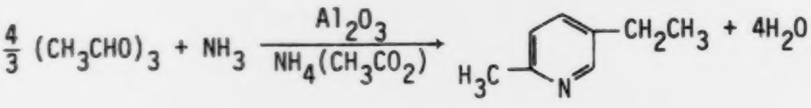
*AROMATIC COMPOUNDS, ETC.

Figure 5-10. Benzoyl Peroxide Manufacture

product) constitute the bulk of the process waste; residual hydrogen peroxide (0.03 kg/kg product) and benzoic acid and other aromatic compounds (0.01 kg/kg product) are the minor portions of the process wastes. The Federal Water Pollution Control Act Amendments will require that the benzoic acid and other aromatic compounds be removed from the waste stream prior to discharge to receiving water courses or municipal sewer systems. The solids separated as sludges in the lagoons are treated by biological sludge digestion, and the residues are incinerated.

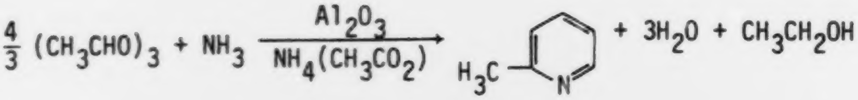
Pyridines (2-Methyl, 5-Ethyl Pyridine and α-Picoline) SIC 28651(23, 25, 34)

Because of increased demands which could not be satisfied by pyridines/pyridine bases produced from the coking process, commercial production of these compounds by synthesis has increased sharply. Total capacity in 1973 was about 18,000 metric tons (40 million pounds). The major producer of methyl ethyl pyridine (MEP) and α-picoline was the Union Carbide Corporation; other producers of α-picoline included Koppers Company, Inc., Nepara Chemical Company, Inc., and Reilly Tar and Chemical Corporation. The type of plant shown in Figure 5-11 accounted for over 50 percent of synthetic pyridines production. Typical plant capacity was 35,000 metric tons/year. Paraldehyde and ammonia are reacted in the presence of an aluminum oxide catalyst and ammonium acetate to give yields in the range of 70 percent of pyridine compounds — mainly 2-methyl, 5-ethyl pyridine, containing about 10 percent α-picoline (methyl pyridine). The two concurrent reactions are:



2-methyl, 5-ethyl pyridine

and:



2-methyl pyridine (α-picoline)

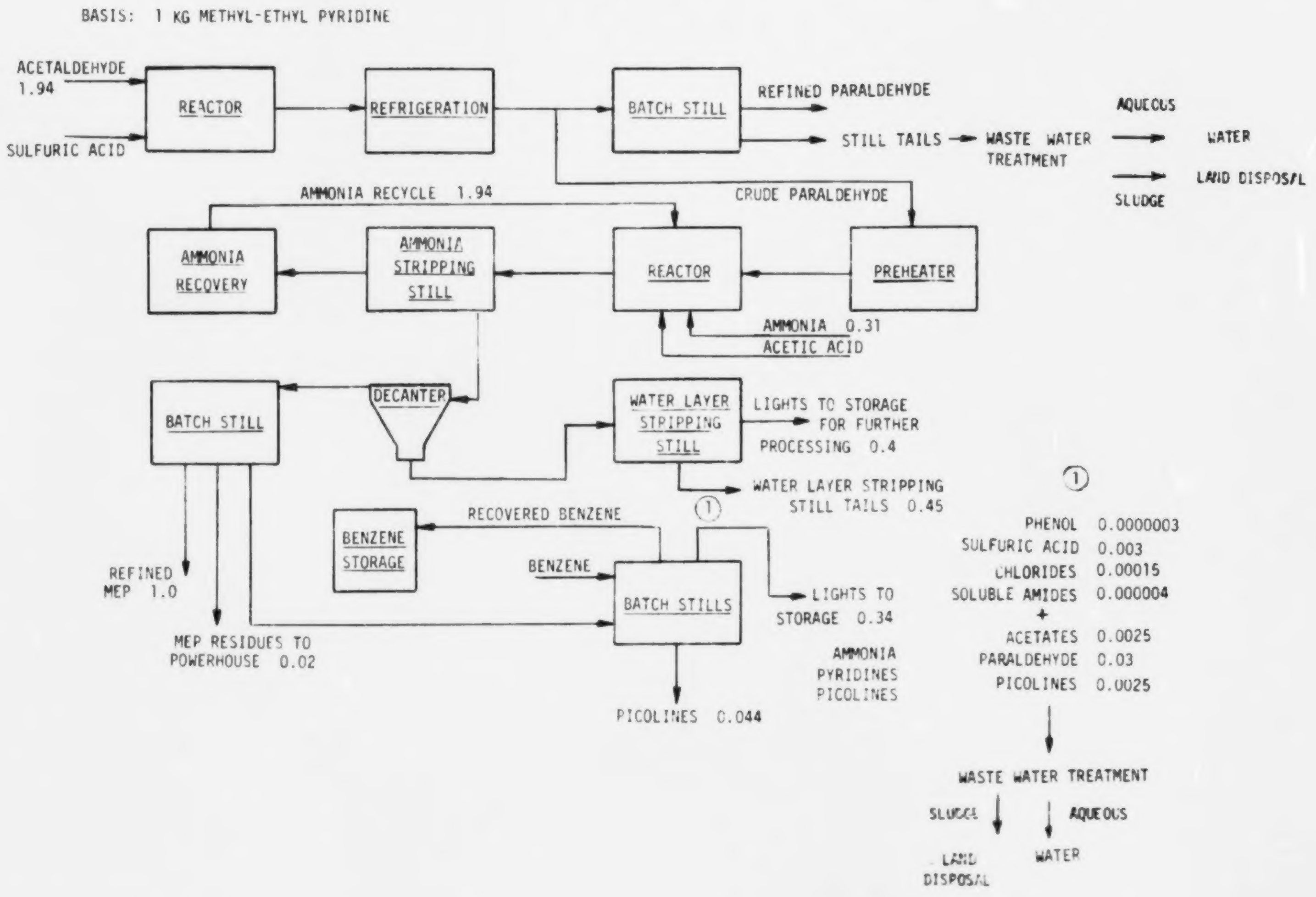

BASIS: 1 KG METHYL-ETHYL PYRIDINE
ACETALDEHYDE 1.94
SULFURIC ACID
REACTOR
REFRIGERATION
BATCH STILL
REFINED PARALDEHYDE
STILL TAILS
WASTE WATER TREATMENT
AQUEOUS
WATER
SLUDGE
LAND DISPOSAL
AMMONIA RECYCLE 1.94
CRUDE PARALDEHYDE
AMMONIA RECOVERY
AMMONIA STRIPPING STILL
REACTOR
PREHEATER
AMMONIA 0.31
ACETIC ACID
BATCH STILL
DECANTER
WATER LAYER STRIPPING STILL
LIGHTS TO STORAGE FOR FURTHER PROCESSING 0.4
WATER LAYER STRIPPING STILL TAILS 0.45
①
BENZENE STORAGE
RECOVERED BENZENE
BENZENE
BATCH STILLS
LIGHTS TO STORAGE 0.34
AMMONIA
PYRIDINES
PICOLINES
REFINED MEP 1.0
MEP RESIDUES TO POWERHOUSE 0.02
PICOLINES 0.044
①
PHENOL 0.0000003
SULFURIC ACID 0.003
CHLORIDES 0.00015
SOLUBLE AMIDES 0.000004
+
ACETATES 0.0025
PARALDEHYDE 0.03
PICOLINES 0.0025
WASTE WATER TREATMENT
SLUDGE
AQUEOUS
LAND DISPOSAL
WATER

Figure 5-11. Pyridines (2-Methyl, 5-Ethyl Pyridine and α-Picoline) Manufacture

The paraldehyde used as raw material is produced at the plant site by polymerizing acetaldehyde with an acid catalyst:

$$3CH_3CHO \xrightarrow{H_2SO_4} (CH_3CHO)_3$$

Overall, the manufacturing process involves polymerizing acetaldehyde to the trimer, and then feeding ammonia, acetic acid and preheated crude paraldehyde to the reactor. The reactor effluent is fed to an ammonia stripping tower for recovery and recycle of unreacted ammonia. The stripped mixture is separated in a decanter into an upper layer, containing the pyridine and by-products, and a lower layer, containing soluble acetates, amides, and other impurities. The decanted crude "pyridine" is refined in a batch still. The higher boiling fraction is refined methyl ethyl pyridine. The overhead, composed mainly of picoline, other pyridines, ammonia and paraldehyde, is distilled again into an overhead cut, stored for further recovery of by-products, a recovered benzene fraction, and refined picolines. The decanter water layer is batch distilled in a stripping still, with the overhead "cut" going to storage prior to further processing, and the tails constituting the major process waste stream. Other process wastes include a very small quantity of still tails from the batch still used to produce by-product refined paraldehyde, and the methyl ethyl pyridine (MEP) residues from the batch still producing refined MEP.

The stripping still tails quantity is approximately 0.038 kg/kg refined MEP; the major contaminants are paraldehyde (0.03 kg/kg MEP), sulfuric acid (0.003 kg/kg MEP), pyridines and picolines (0.0025 kg/kg MEP) and soluble acetates (0.0025 kg/kg MEP). These constituents currently go to waste water treatment; they are hazardous components which must be removed from waste water treatment effluent, as per the Federal Water Pollution Control Act Amendments. The MEP residues from the refined MEP still are about 0.02 kg/kg MEP product; they are currently fed to the powerhouse as a fuel. Because of the heterocyclic compounds present, the MEP residues are considered a hazardous process waste.

Fluorocarbons SIC 28692 (25, 35, 36)

The production of fully substituted fluorochloromethanes in the United States in 1973(3) totaled 373,000 metric tons (823 million pounds). Of this quantity, 222,000 metric tons was dichlorodifluoromethane; the remainder was trichlorofluoromethane. Major manufacturers for both products included E. I. duPont de Nemours and Company, Inc., Allied Chemical Corporation, Kaiser Aluminum and Chemical Corporation, Pennwalt Corporation, Racon, Inc., and Union Carbide Corporation.(4) Typical plant sizes ranged to as high as 80,000 metric tons capacity per year. The fluorocarbons of this series are used as aerosol propellants, refrigerants, and solvents.

A hypothetical characteristic continuous production system is shown in Figure 5-12. An initial catalyst charge of antimony trichloride (equivalent to all of the antimony chloride which will be discharged as spent catalyst during the next year of operation) has been placed in the reactor and chlorinated prior to the start-up. Carbon tetrachloride (both fresh feed and recycle) and anhydrous hydrogen fluoride are fed continuously to the reactor system. They react as follows:

$$CCl_4 + HF \xrightarrow{Sb^{+5}} CCl_3F + HCl \qquad 20\%$$

$$CCl_4 + 2HF \xrightarrow{Sb^{+5}} CCl_2F_2 + 2HCl \qquad 80\%$$

Other reactions which may take place are:

$$CCl_4 + 3HF \xrightarrow{Sb^{+5}} CClF_3 + 3HCl$$

and

$$CCl_4 + 4HF \longrightarrow CF_4 + 4HCl$$

The crude fluorocarbon product passes through a stripping still, with hydrogen chloride removed and sent to by-product sales or use, and carbon tetrachloride bottoms recycled to the reactor. The partially purified product stream is next stripped of its HF, which is sent to recovery.

The fluorocarbon stream is washed with caustic soda solution to remove traces of acid and dried with sulfuric acid. The fluorocarbons are then separated in a fractionating column and sent to storage.

The sodium hydroxide and sulfuric acid bleed streams are neutralized and sent to the plant industrial outfall. The spent catalyst is discharged

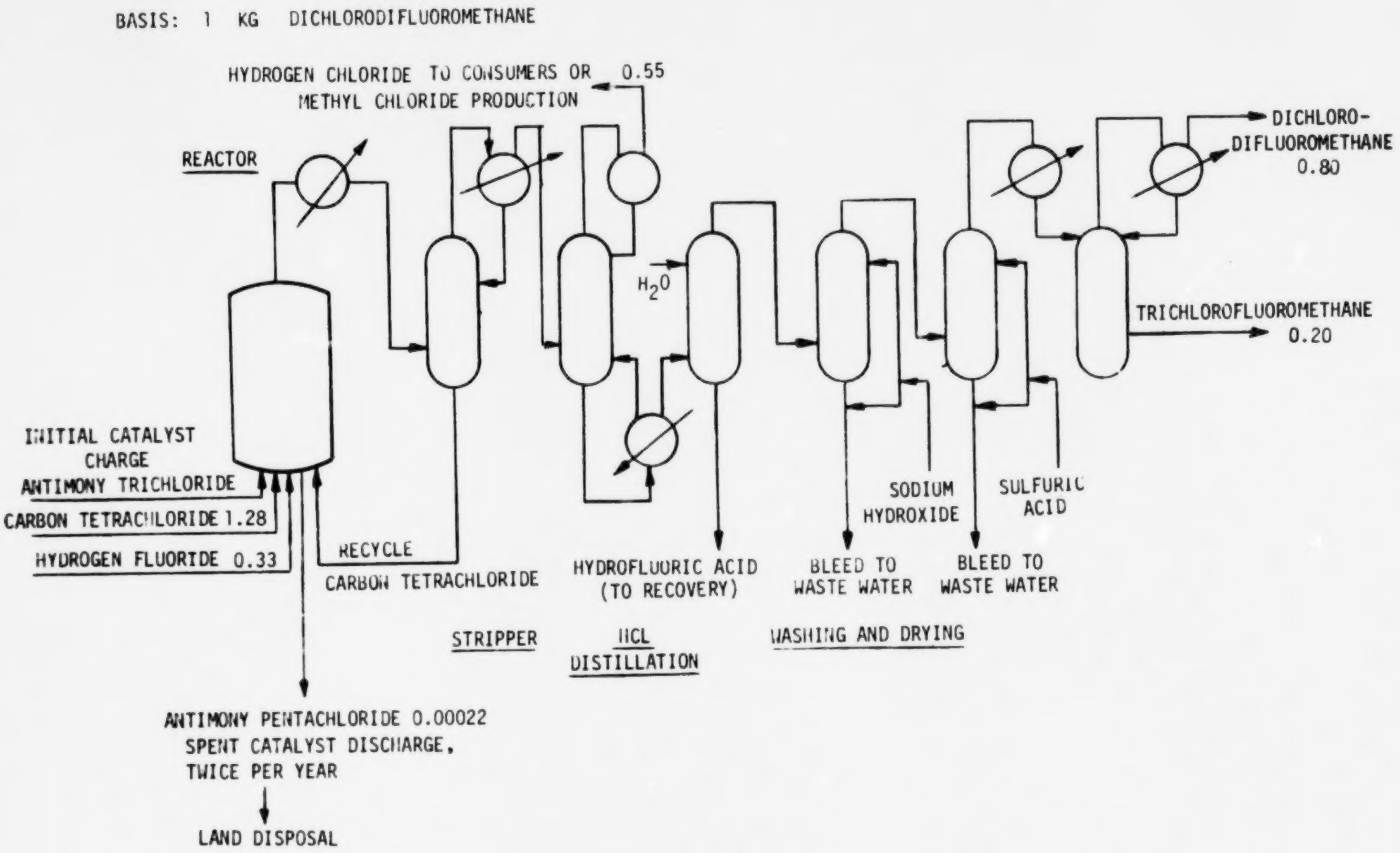

BASIS: 1 KG DICHLORODIFLUOROMETHANE
HYDROGEN CHLORIDE TO CONSUMERS OR 0.55
METHYL CHLORIDE PRODUCTION
REACTOR
DICHLORO-
DIFLUOROMETHANE
0.80
H2O
TRICHLOROFLUOROMETHANE
0.20
INITIAL CATALYST
CHARGE
ANTIMONY TRICHLORIDE
CARBON TETRACHLORIDE 1.28
HYDROGEN FLUORIDE 0.33
RECYCLE
CARBON TETRACHLORIDE
SODIUM
HYDROXIDE
SULFURIC
ACID
HYDROFLUORIC ACID
(TO RECOVERY)
BLEED TO
WASTE WATER
BLEED TO
WASTE WATER
STRIPPER
HCL
DISTILLATION
WASHING AND DRYING
ANTIMONY PENTACHLORIDE 0.00022
SPENT CATALYST DISCHARGE,
TWICE PER YEAR
LAND DISPOSAL

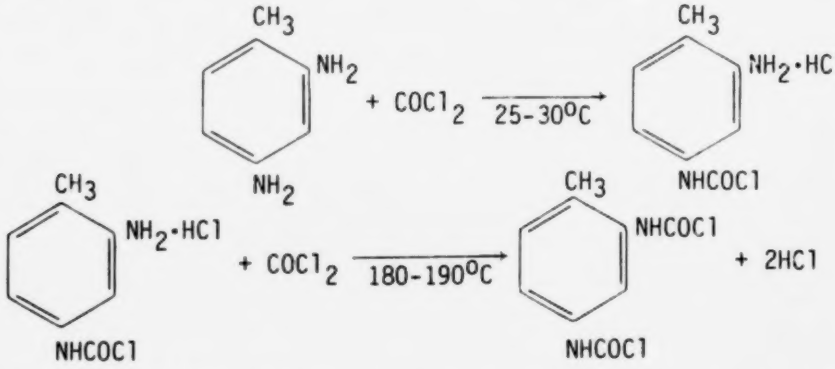
Figure 5-12. Fluorocarbons Manufacture

from the reactor of the typical plant twice per year, at the "rate" of 0.00022 kg/kg product. It contains antimony pentachloride, which is considered a highly dangerous component, and is discharged to the land. Due to the toxicity of the antimony chloride constituent, the waste discharge is deemed hazardous.

Toluene Diisocyanate SIC 28651(20, 23, 25, 36)

Mixed toluene diisocyanates (the 80/20 mixture of toluene-2,4-diisocyanate and toluene-2,6-diisocyanate) production in the United States in 1973(3) was 230,000 metric tons (506 million pounds). The total for all isocyanic acid derivatives was 395,000 metric tons. The major producers of the mixed toluene diisocyanates(3) in 1973 were Allied Chemical Corporation (Specialty Chemicals Division), BASF Wyandotte Corporation, E. I. duPont de Nemours and Company, Inc., General Tire and Rubber Company, Mobay Chemical Company, Olin Corporation, Rubicon Chemicals Inc., and Union Carbide Corporation. The toluene isocyanates (TDIs) are major intermediates for the production of the polyurethanes. A typical TDI continuous process plant capacity is 27,500 metric tons (60 million pounds) per year.

Starting raw materials for the hypothetical typical continuous process plant flow diagram of Figure 5-13 are a solution of toluene-2,4-diamine (in mixture with toluene-2,6-diamine) and gaseous phosgene. These compounds are fed to two jacketed, agitator-equipped reactor kettles, in series, along with recycled "inert" solvent (in this instance, o-dichlorobenzene containing dissolved recycled phosgene), where the following reactions take place:



(Reactor 1)

(Reactor 2)

(Note: For ease of presentation, only the preparation of 2,4-TDI is shown throughout this text. The 2,6-TDI isomer preparation is similar to the preparation of the 2,4-TDI.

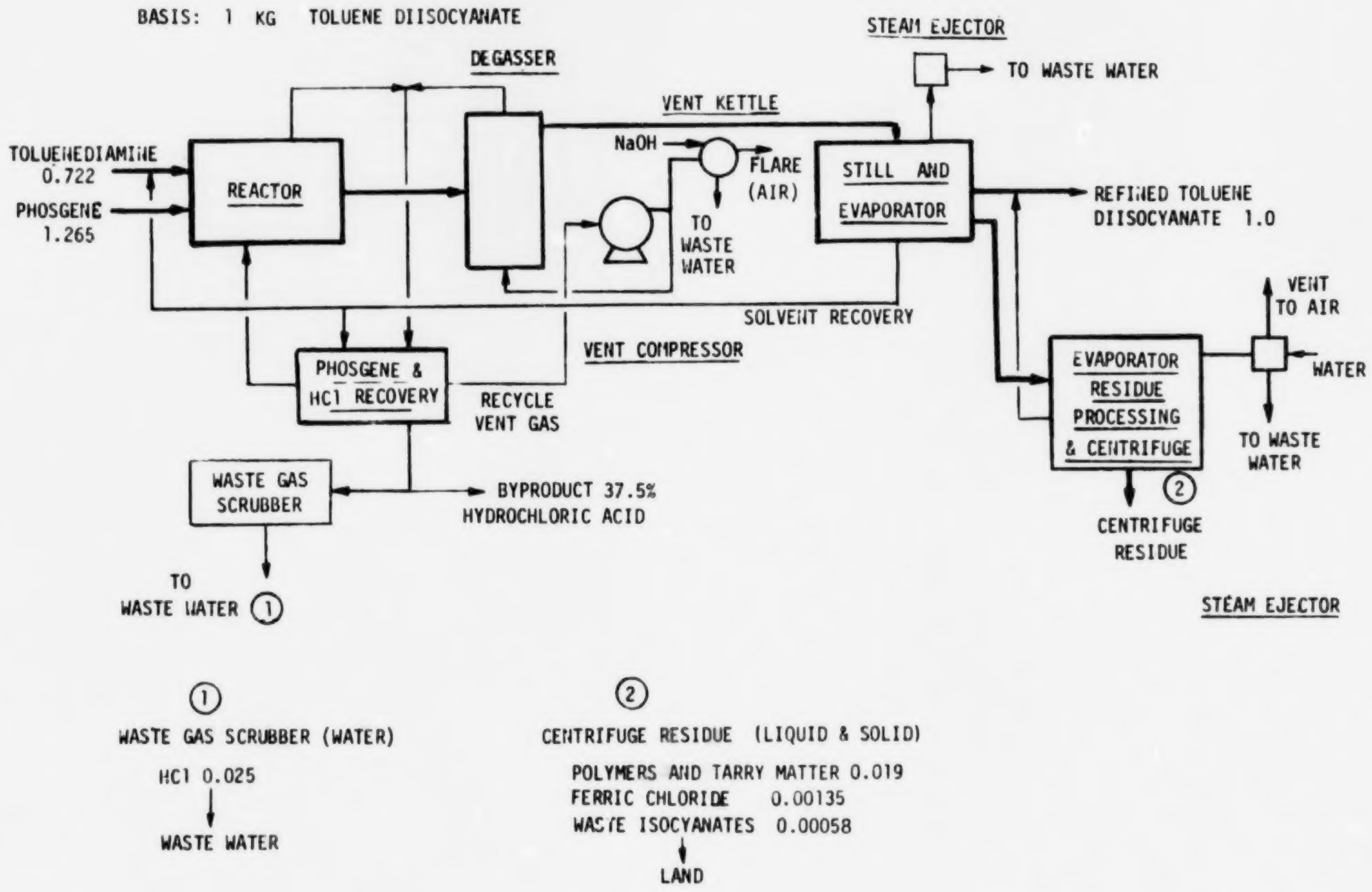
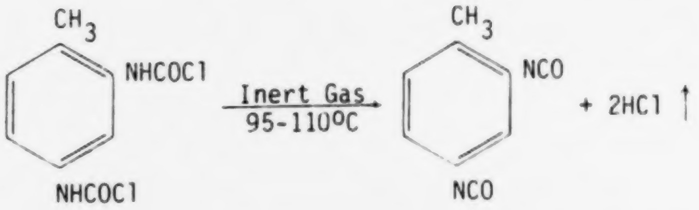

BASIS: 1 KG TOLUENE DIISOCYANATE
TOLUENEDIAMINE 0.722
PHOSGENE 1.265
REACTOR
DEGASSER
VENT KETTLE
NaOH
FLARE (AIR)
TO WASTE WATER
STEAM EJECTOR
TO WASTE WATER
STILL AND EVAPORATOR
REFINED TOLUENE DIISOCYANATE 1.0
SOLVENT RECOVERY
VENT COMPRESSOR
PHOSGENE & HCl RECOVERY
RECYCLE VENT GAS
WASTE GAS SCRUBBER
BYPRODUCT 37.5% HYDROCHLORIC ACID
TO WASTE WATER ①
EVAPORATOR RESIDUE PROCESSING & CENTRIFUGE
②
CENTRIFUGE RESIDUE
VENT TO AIR
WATER
TO WASTE WATER
STEAM EJECTOR
①
WASTE GAS SCRUBBER (WATER)
HCl 0.025
WASTE WATER
②
CENTRIFUGE RESIDUE (LIQUID & SOLID)
POLYMERS AND TARRY MATTER 0.019
FERRIC CHLORIDE 0.00135
WASTE ISOCYANATES 0.00058
LAND

Figure 5-13. Toluene Diisocyanate Manufacture

An excess of phosgene is used; the unreacted phosgene and the hydrogen chloride liberated constitute the major components of the gas stream exiting the second reactor. The reactor exit gas goes to a phosgene recovery/by-product hydrochloric acid recovery system. Because of the extreme toxicity of phosgene, stringent safety measures are used throughout the manufacturing process. Degassers, seal pots, vent kettles, scrubbers and flare towers are used to recover and reuse phosgene, recover/abate hydrogen chloride discharge, and prevent escape of vent phosgene gases to the atmosphere.

The phosgene recovered is recycled in solution in recovered solvent and fed to the first reactor. The by-product hydrochloric acid (2.32 kg 37.5 percent HCl/kg TDI product) is recovered from the gas stream after removal of the phosgene and is sent to storage or sales. The waste gas scrubber effluent contains the residual hydrogen chloride (0.025 kg/kg TDI product) dissolved in water; it is sent to neutralization and then to the plant industrial outfall.

The conversion to TDI takes place after the reactor liquid has been fed to the degasser, in accordance with the following reaction:



An inert gas (natural gas) is blown through the solution to "degas" the evolved HCl. The degasser vent gas is sent to the "phosgene and HCl recovery system", where the HCl, as noted above, is recovered as by-product hydrochloric acid, and the natural gas is recycled to the vent gas compressor.

The crude solution of TDI's from the degassers is fed to the stills and evaporators to recover solvent and purify the TDI's. The purified TDI is sent to storage. The recovered solvent is recycled for use in recovery of phosgene and as a solvent for the toluene diamine feed. The evaporator residue is processed and centrifuged; the centrifugate is recovered TDI which is sent to storage, and the centrifuge residue is a process waste sent to land disposal, at the rate of approximately 0.021 kg per kg of TDI product. The material contains 90 percent polymers and tarry matter, 6 percent ferric chloride (largely from process impurities) and 3 percent waste isocyanates. It is considered a hazardous waste stream, containing highly dangerous components (the waste isocyanates).

Vinyl Chloride Monomer SIC 28692(20, 21, 25, 37)

The production rates in 1973 for vinyl chloride monomer (VCM) and for ethylene dichloride (EDC), the intermediate used in the majority of manufacturing processes, were 2,432,000 metric tons (5,351 million pounds) and 4,215,000 metric tons (9,293 million pounds)(3). In 1973 there were ten major producers(4): Allied Chemical Corporation (Specialty Chemicals Division), American Chemical Company, B. F. Goodrich Company (B. F. Goodrich Chemical Company Division), Continental Oil Company, Dow Chemical Company, Tenneco Chemicals Incorporated, Monochem Incorporated, PPG Industries, Inc., Shell Oil Company (Shell Chemical Company Division) and Ethyl Corporation. A typical plant size can produce 136,000 metric tons per year. Plant capacities ranged from 27,000 metric tons to 317,500 metric tons per year for the major process system employed.(21)

The process flow diagram of Figure 5-14 is a composite typical operation for the production of vinyl chloride from ethylene and chlorine. Ethylene dichloride is produced continuously by the liquid phase catalyzed addition chlorination reaction between ethylene and chlorine, fed as gaseous reactants to a pressurized vessel. The reaction which takes place is:

$$H_2C{=}CH_2 + Cl_2 \xrightarrow[100^\circ C]{FeCl_3} ClH_2C{-}CH_2Cl \text{ (EDC)}$$

The catalyst employed is ferric chloride suspended in liquid ethylene dichloride. The product ethylene dichloride is liquefied, scrubbed with dilute caustic soda solution, filtered and distilled. The heavy ends from the still (0.0104 kg per kg product VCM) are a hazardous process waste sent to land disposal. The heavy ends contain highly dangerous components — ethylene dichloride (23 percent), 1,1,2-trichloroethane (38 percent) and tetrachloroethane (38 percent) — which are bioaccumulative.

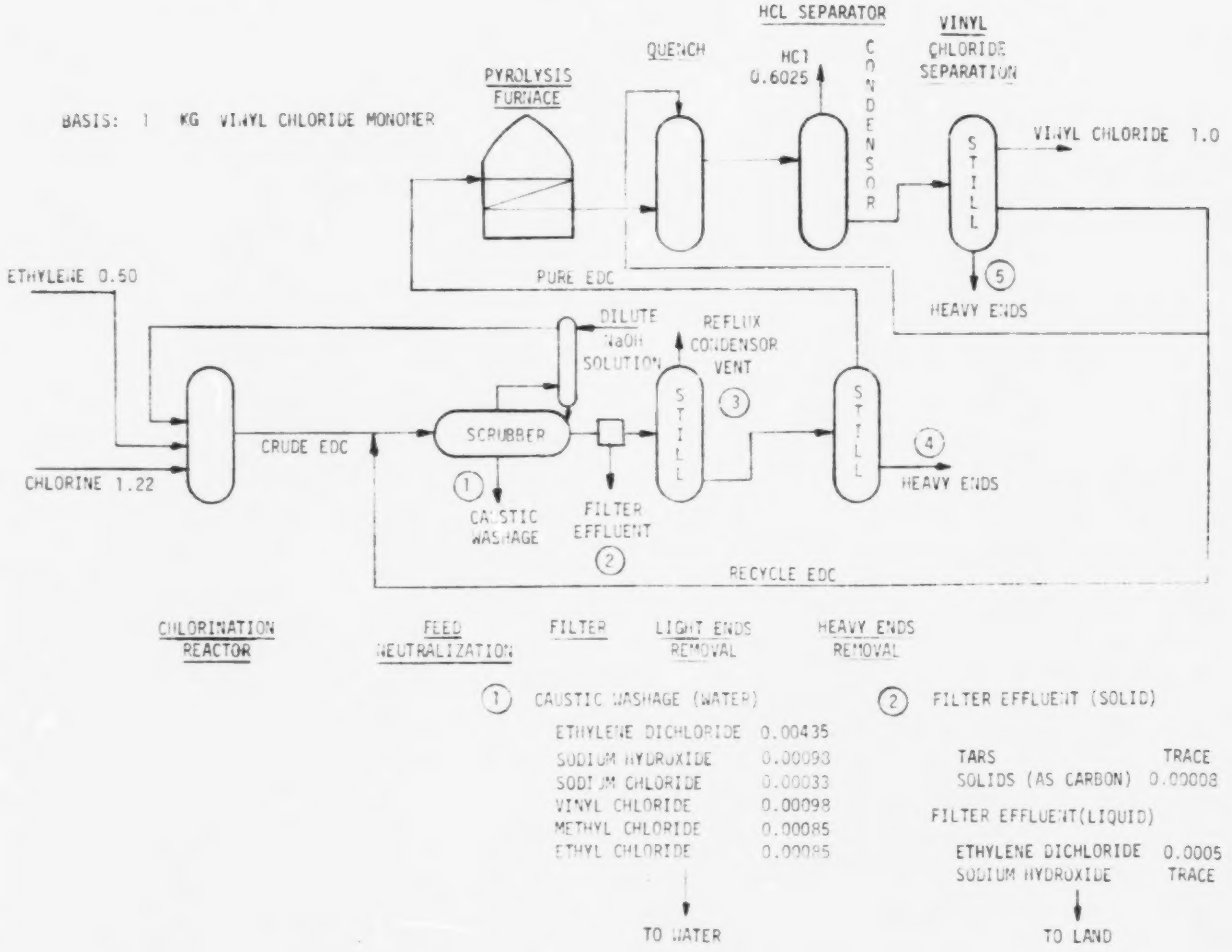

BASIS: 1 KG VINYL CHLORIDE MONOMER
PYROLYSIS FURNACE
QUENCH
HCL SEPARATOR
HC1 0.6025
CONDENSOR
VINYL CHLORIDE SEPARATION
VINYL CHLORIDE 1.0
STILL
5
HEAVY ENDS
ETHYLENE 0.50
CHLORINE 1.22
PURE EDC
DILUTE NaOH SOLUTION
REFLUX CONDENSOR VENT
3
CRUDE EDC
SCRUBBER
STILL
STILL
4
HEAVY ENDS
1
CAUSTIC WASHAGE
FILTER EFFLUENT
2
RECYCLE EDC
CHLORINATION REACTOR
FEED NEUTRALIZATION
FILTER
LIGHT ENDS REMOVAL
HEAVY ENDS REMOVAL
1 CAUSTIC WASHAGE (WATER)
ETHYLENE DICHLORIDE 0.00435
SODIUM HYDROXIDE 0.00093
SODIUM CHLORIDE 0.00033
VINYL CHLORIDE 0.00098
METHYL CHLORIDE 0.00085
ETHYL CHLORIDE 0.00085
TO WATER
2 FILTER EFFLUENT (SOLID)
TARS TRACE
SOLIDS (AS CARBON) 0.00008
FILTER EFFLUENT(LIQUID)
ETHYLENE DICHLORIDE 0.0005
SODIUM HYDROXIDE TRACE
TO LAND

Figure 5-14. Vinyl Chloride Monomer Manufacture

③

VENT ON REFLUX CONDENSOR (GAS)

ETHANE	0.0049
ETHYLENE DICHLORIDE	0.012
METHANE	0.0049

↓

TO AIR

④

HEAVY ENDS

ETHYLENE DICHLORIDE	0.0024
1,1,2 TRICHLOROETHANE	0.004
TETRACHLOROETHANE	0.004
TARS	TRACE

↓

TO LAND

⑤

HEAVY ENDS

HEAVY ENDS	0.037
ETHYLENE DICHLORIDE	0.0008
TARS	0.00005
SOLIDS ASH	0.0002

↓

TO LAND

Figure 5-14. Vinyl Chloride Monomer Manufacture (Continued)

The purified EDC from the still is fed to the pyrolysis furnace for the production of vinyl chloride monomer, in accordance with the following reaction:

$$ClCH_2CH_2Cl \xrightarrow[480\text{-}510^{\circ}C]{Catalyst} HCl + CH_2{=}CH_2Cl \qquad (VCM)$$

The reaction takes place in the vapor phase, at 450-620 x 10^3 newtons/meter^2 (50-75 psig). The catalysts employed may be activated carbon or pumice. When mercuric chloride is employed as a catalyst for this reaction, lower temperatures (450°C) and higher pressures (520-930 x 10^3 newtons/meter^2) are used. Conversion per pass through the reactor is 50 percent; with recycle, the reactor pyrolysis yield is 95 to 96 percent.

The product gas stream from the furnace, containing VCM, EDC and HCl, is quenched with recycled liquid EDC and condensed. The hydrogen chloride is separated in the condenser since it remains (as the sole constituent) in the gas phase, and is sent to recovery or to use in an oxychlorination unit for the production of EDC by reaction with ethylene.

The liquid effluent from the condenser is sent to a still where it is separated into VCM product, recycle EDC, and heavy ends (about 0.038 kg/kg VCM product). The heavy ends are a hazardous process waste sent to land disposal. In this case they are composed of 97 percent higher halogenated hydrocarbons, 2 percent EDC and 1 percent tars, and are considered highly dangerous. When mercuric chloride is used as catalyst, there is also a discharge of mercuric "hydroxide" (hydrated oxide) to land in the filter solids, estimated at 5 x 10^{-6} kg/kg VCM.

Methyl Methacrylate Monomer SIC 28692(20, 37)

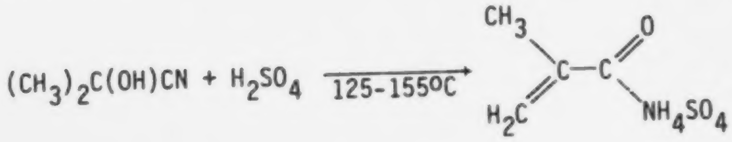
Production reported for methyl methacrylate monomer in 1973 was 320,000 metric tons (706 million pounds).(3) The major producers were American Cyanamid Company, E. I. duPont de Nemours and Company, and Rohm and Haas Company. Virtually all of the production was converted to polymer. A typical plant size for the production of monomer is 55,000 metric tons per year.

All of the methyl methacrylate produced commercially in the United States is based upon the use of acetone, hydrogen cyanide and methanol as raw materials in the acetone cyanohydrin process. The flow diagram of Figure 5-15 presents a typical production flow based on the acetone cyanohydrin process used for commercial production in this country. Acetone cyanohydrin is produced from the acetone and hydrogen cyanide fed continuously to the cyanohydrin reactor in accordance with the following reaction:

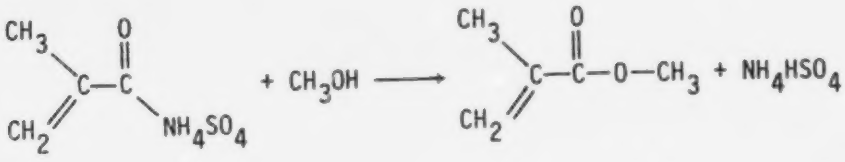
$$CH_3COCH_3 + HCN \xrightarrow[NaOH]{} (CH_3)_2C(OH)CN$$

Sodium hydroxide is employed as the alkaline catalyst in a cooled reaction kettle. The excess base is neutralized in the reactor effluent stream with sulfuric acid. Sodium sulfate crystallizes from the neutralized crude acetone cyanohydrin stream and is removed by filtration. The sodium sulfate, after washing, is sent to land disposal (0.1 kg/kg product). The crude acetone cyanohydrin is fed to a two-stage distillation unit for concentration. The acetone and water overhead of the first still are recycled to the cyanohydrin reactor, and the rest of the water is removed from the cyanohydrin in the second still.

The acetone cyanohydrin is then blended with concentrated sulfuric acid in a cooled hydrolysis kettle, and heated after blending to form methacrylamide sulfate:



The effluent from the hydrolysis kettle is reacted continuously with methanol in an esterification column to produce methyl methacrylate:



Inhibitors, such as hydroquinone, are added during the process to prevent polymerization.

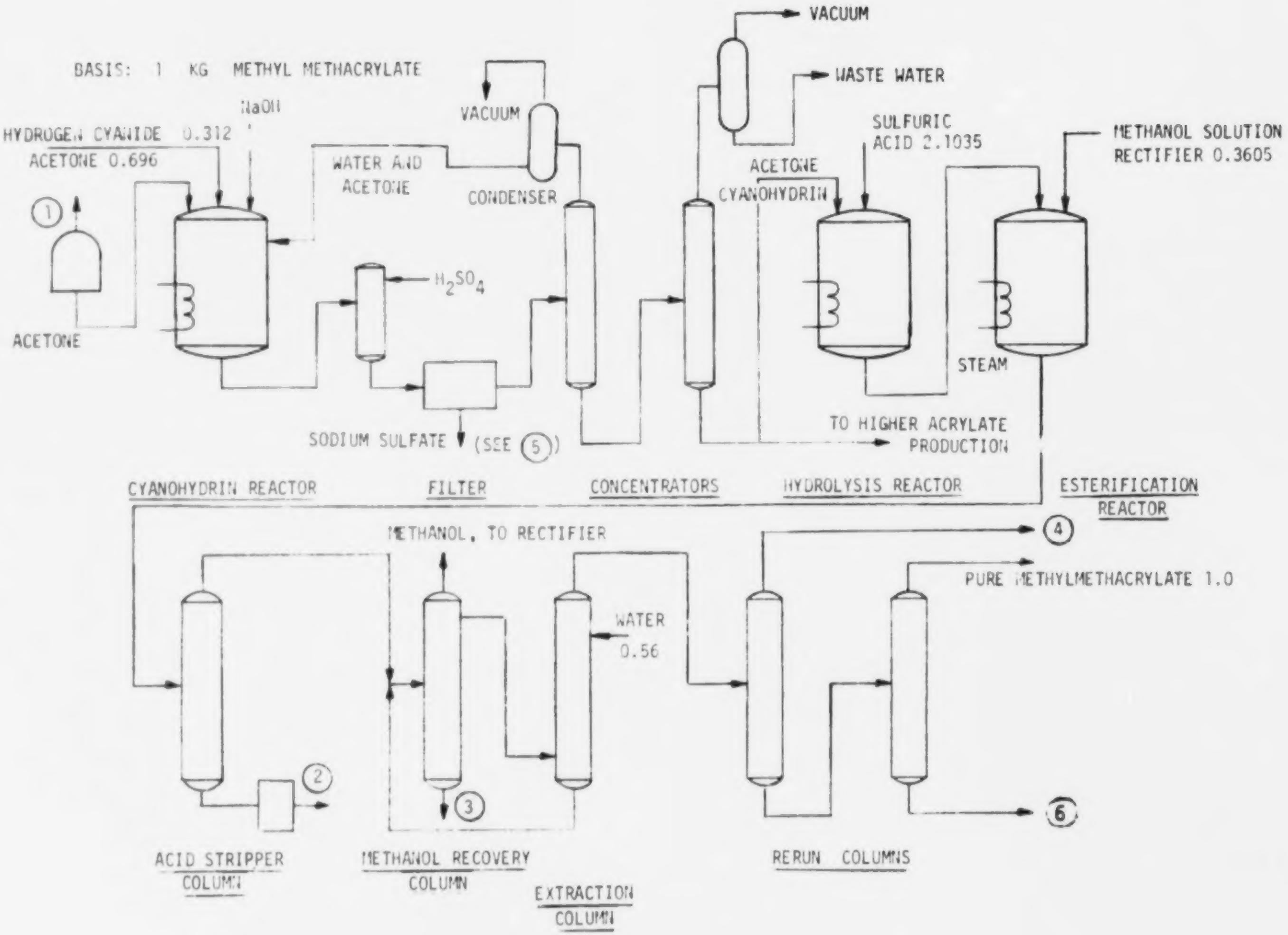

VACUUM
BASIS: 1 KG METHYL METHACRYLATE
WASTE WATER
NaOH
VACUUM
HYDROGEN CYANIDE 0.312
ACETONE 0.696
WATER AND ACETONE
SULFURIC ACID 2.1035
METHANOL SOLUTION RECTIFIER 0.3605
ACETONE CYANOHYDRIN
CONDENSER
①
H_2SO_4
ACETONE
STEAM
TO HIGHER ACRYLATE PRODUCTION
SODIUM SULFATE (SEE ⑤)
CYANOHYDRIN REACTOR
FILTER
CONCENTRATORS
HYDROLYSIS REACTOR
ESTERIFICATION REACTOR
METHANOL, TO RECTIFIER
④
PURE METHYLMETHACRYLATE 1.0
WATER 0.56
②
③
⑥
ACID STRIPPER COLUMN
METHANOL RECOVERY COLUMN
EXTRACTION COLUMN
RERUN COLUMNS

Figure 5-15. Methyl Methacrylate Manufacture

WASTE STREAMS: (METHYL METHACRYLATE)

① VENT ON ACETONE FEED TANKS (AIR)

ACETONE	0.0295
HYDROGEN CYANIDE	0.00315

↓

AIR

② ACID RECOVERY WASTE (LIQUID)

METHANOL	0.012
POLYMERS	0.006
AMMONIUM METHACRYLATE	0.0199
AMMONIUM ACETATE	0.0009
AMMONIUM CYANIDE	0.0195
AMMONIUM ACID SULFATE	1.2593
RESIDUAL SULFURIC ACID	0.9604

↓

AMMONIUM SULFATE RECOVERY
SULFURIC ACID RECOVERY
OR LAND

⑤ FILTER CAKE (SOLID)

SODIUM SULFATE	0.1015

↓

BYPRODUCT SALES
OR LAND

③ HEAVY ENDS OF METHANOL RECOVERY

HYDROQUINONE	0.001125
POLYMERS	0.075

↓

LAND

④ LIGHT ENDS REMOVAL COLUMN (LIQUID)

ACETONE	0.02645
HYDROQUINONE	0.00025
METHYL METHACRYLATE	0.0013
HYDROGEN CYANIDE	0.00025

↓

WATER

⑥ HEAVY ENDS
(POLYMERIC RESIDUE)

↓

LAND

Figure 5-15. Methyl Methacrylate Manufacture (Continued)

The esterification column effluent is transferred continuously to the acid stripper column, where the stream is split into an overhead containing crude methyl methacrylate, methanol and water, and an acid residue. The acid residue, on a water-free basis, is about 2.28 kg per kg of product methyl methacrylate; it contains (water-free basis) 55 percent ammonium acid sulfate, 42 percent residual sulfuric acid, and 3 percent "organics" (ammonium methacrylate, methanol, polymers and ammonium cyanide). It constitutes a hazardous process waste which is either sent to a recovery unit or discharged to sewer.(37)

The recovery unit is either an ammonium sulfate recovery plant (where the majority of the organics present are adsorbed on the crystals of ammonium sulfate produced) or a spent sulfuric acid recovery plant. The spent sulfuric acid recovery plant would be required to operate a pyrolysis unit at temperatures over 1000°C, decomposing the organics and the ammonium compounds to give a gas stream containing SO_2, CO_2, N_2, H_2O and O_2. The gas stream would be dried and "converted" to SO_3 and then to H_2SO_4 for reuse.

The overhead from the acid stripper column is distilled in the "methanol recovery" column. Methyl methacrylate containing some methanol is taken off as a mid-cut; the overhead cut is methanol which is recycled to the rectifier. The bottoms from this column are about 0.086 kg/kg product and constitute a hazardous waste stream to land disposal containing 87 percent polymers and 13 percent hydroquinone.

The mid-cut of crude methyl methacrylate is stripped of its last traces of methanol by water extraction. The water-methanol extract is cycled to the methanol recovery column. The washed monomer is distilled to yield dry methyl methacrylate product. The light ends from the first rerun column (about 0.029 kg/kg product) go to the plant industrial outfall. They contain hazardous components whose removal via land-based treatment techniques would be required by the Federal Water Pollution Control Act Amendments. The hazardous components would be destined for land disposal.

Acrylonitrile SIC 28692(20, 21, 25)

Production of acrylonitrile in the United States during 1973 was 614,000 metric tons (1,354 million pounds).(3) The major producers were: American Cyanamid Company, B. F. Goodrich Company (B. F. Goodrich Chemical

Company Division), the duPont Company, the Monsanto Company, and Vistron Corporation (Standard Oil Company of Ohio).(4) The major part of the acrylonitrile produced is used in the manufacture of synthetic fibers, in acrylonitrile plastics, and in cyanoethylation of cotton to improve its wear and life characteristics.

The Sohio process presented in Figure 5-16 is used for production of acrylonitrile by more than 35 plants throughout the world. Aggregate production by this process worldwide exceeds 1,360,000 metric tons. Typical production lines range in size from 4,500 metric tons to about 160,000 metric tons per year.

Propylene, fertilizer grade anhydrous ammonia, and air are fed continuously to a fluid bed catalytic reactor operating at relative low pressure (138 to 310 kilonewtons per square meter or 20 to 45 pounds per square inch) and temperatures between 400 and 510°C, (752 and 950°F).

The catalyst used currently is a solid antimony-uranium oxide mixture; older plants use a 50-60 percent bismuth phosphomolybdate catalyst on silica. In the vapor phase, a number of concurrent reactions take place, producing acrylonitrile, hydrogen cyanide, acetonitrile, water, carbon monoxide, and propane as major products. These may be summarized as follows:

$$4H_2C{=}CHCH_3 + 4NH_3 + 5O_2 \xrightarrow[400\text{-}510^{\circ}C]{\text{Catalyst}}$$

$$CH_2{=}CHCN + C_3H_8 + 2CH_3CN + 9H_2O + CO + HCN$$

Heat is absorbed from the highly exothermic reaction by generating high pressure steam from boiler feedwater. Steam may also be added to the reactor as a diluent. The reactor effluent is scrubbed with water in a countercurrent absorber. The off-gas from the absorber contains, as major impurities, carbon monoxide, propylene and propane, with a lesser quantity of acrylonitrile, and traces of ammonia and acetonitrile; it is flared as a safety measure. The water solution of organic materials (acrylonitrile, acetonitrile, hydrogen cyanide, and heavy ends) goes to an acrylonitrile recovery column where wet acrylonitrile-hydrogen cyanide is taken off as an overhead stream. Acetonitrile bottoms from the column are purified by distillation. The bottoms from the first acetonitrile purification distillation

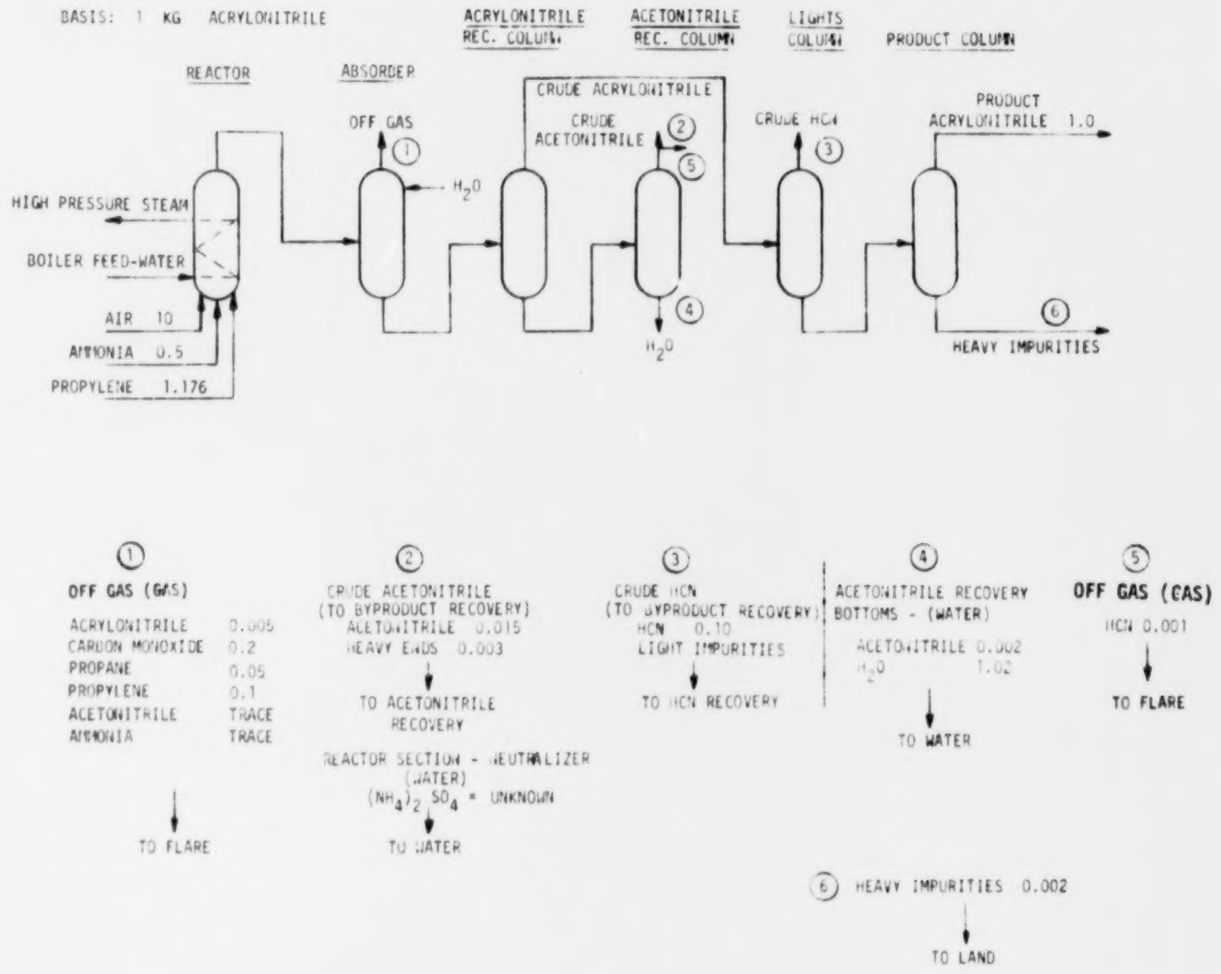

BASIS: 1 KG ACRYLONITRILE
REACTOR
ABSORBER
ACRYLONITRILE REC. COLUMN
ACETONITRILE REC. COLUMN
LIGHTS COLUMN
PRODUCT COLUMN
HIGH PRESSURE STEAM
BOILER FEED-WATER
AIR 10
AMMONIA 0.5
PROPYLENE 1.176
OFF GAS
①
H_2O
CRUDE ACRYLONITRILE
CRUDE ACETONITRILE
②
⑤
④
H_2O
CRUDE HCN
③
PRODUCT ACRYLONITRILE 1.0
⑥
HEAVY IMPURITIES
①
OFF GAS (GAS)
ACRYLONITRILE 0.005
CARBON MONOXIDE 0.2
PROPANE 0.05
PROPYLENE 0.1
ACETONITRILE TRACE
AMMONIA TRACE
TO FLARE
②
CRUDE ACETONITRILE
(TO BYPRODUCT RECOVERY)
ACETONITRILE 0.015
HEAVY ENDS 0.003
TO ACETONITRILE RECOVERY
REACTOR SECTION - NEUTRALIZER (WATER)
$(NH_4)_2SO_4$ = UNKNOWN
TO WATER
③
CRUDE HCN
(TO BYPRODUCT RECOVERY)
HCN 0.10
LIGHT IMPURITIES
TO HCN RECOVERY
④
ACETONITRILE RECOVERY BOTTOMS - (WATER)
ACETONITRILE 0.002
H_2O 1.02
TO WATER
⑤
OFF GAS (GAS)
HCN 0.001
TO FLARE
⑥ HEAVY IMPURITIES 0.002
TO LAND

Figure 5-16. Acrylonitrile (Sohio Process) Manufacture

step consist mainly of water with some acetonitrile (0.002 kg per kg product acrylonitrile). The overhead from the second acetonitrile purification distillation (not shown in the flow diagram) contains about 0.001 kg hydrogen cyanide per kg of acrylonitrile product and is flared as a safety measure. About 0.015 kg of acetonitrile per kg acrylonitrile is recovered for sales or in-plant use. The bottoms from the second acetonitrile distillation column are heavy ends (about 0.003 kg per kg of product acrylonitrile) which are probably nitrile polymers, and constitute a hazardous process waste discharge to land.

The wet acrylonitrile-hydrogen cyanide overhead from the acrylonitrile recovery column is separated by fractional distillation into a crude HCN overhead and a crude acrylonitrile higher boiling cut. The crude HCN is sent to HCN recovery where about 0.10 kg of hydrogen cyanide per pound of product acrylonitrile is recovered for by-product sales or in-plant use. The light impurities from HCN recovery are low in quantity and are flared.

The higher boiling cut of crude acrylonitrile is purified by distillation to produce specification grade product and heavy impurity bottoms. The heavy bottoms (0.002 kg per kg acrylonitrile) are probably higher molecular weight nitriles and polymers and are a hazardous process waste sent to land disposal.

Maleic Anhydride SIC 28692(20, 21, 25)

Maleic anhydride production in the United States during 1973 was 128,000 metric tons (282 million pounds).(3) The seven manufacturers in 1973(4) were Allied Chemical Corporation (Specialty Chemicals Division)*, Tenneco Chemicals Incorporated, Koppers Company Incorporated (Organic Materials Division), the Monsanto Company, Petro-Tex Chemical, Reichhold Chemicals, Incorporated, and USS Chemicals Division of U.S. Steel Corporation. Typical plant sizes ranged from 9,000 to 13,600 metric tons per year.

The process flow diagram for the manufacture of maleic anhydride shown in Figure 5-17 is based on the vapor phase catalytic oxidation of benzene with air, at pressures of 300-400 kilonewtons per square meter (43.5 to 58.0 pounds per square inch). Reactor temperatures are maintained at 400 to 450°C by the use of fused salt cooler with molten salt circulation to produce

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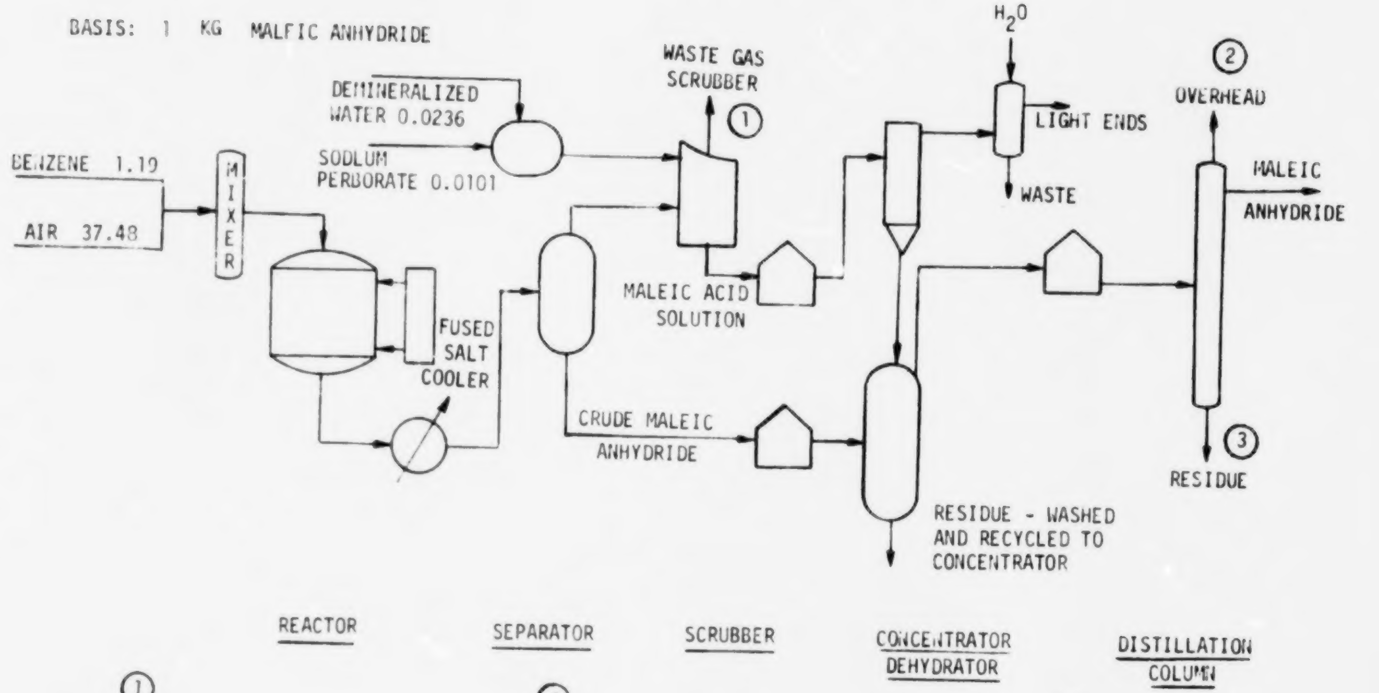
*No longer a manufacturer.


BASIS: 1 KG MALFIC ANHYDRIDE
BENZENE 1.19
AIR 37.48
MIXER
DEMINERALIZED WATER 0.0236
SODLUM PERBORATE 0.0101
WASTE GAS SCRUBBER
①
FUSED SALT COOLER
MALEIC ACID SOLUTION
CRUDE MALEIC ANHYDRIDE
H_2O
LIGHT ENDS
WASTE
RESIDUE - WASHED AND RECYCLED TO CONCENTRATOR
②
OVERHEAD
MALEIC ANHYDRIDE
③
RESIDUE
REACTOR
SEPARATOR
SCRUBBER
CONCENTRATOR DEHYDRATOR
DISTILLATION COLUMN

①

WASTE GAS SCRUBBER (AIR)

BENZENE	0.131
CARBON MONOXIDE	0.78
MALEIC ACID	TRACE

↓ TO AIR (FLARE)

②

DISTILLATION COLUMN OVERHEAD-(WATER)

MALEIC ACID	0.0006
H_2O	0.391

↓ TO WATER

③

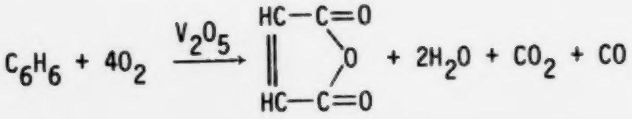
DISTILLATION COLUMN BOTTOMS

MALEIC ANHYDRIDE	0.00375
HIGH BOILERS (TAR, FUMARIC ACID, CHROMOGENIC CMPDS)	0.0265

↓ TO LAND

Figure 5-17. Maleic Anhydride

high pressure steam. The reaction utilizes a solid vanadium pentoxide catalyst supported on an inert porous carried (diatomaceous earth) and is extremely exothermic. It is as follows:



The overall yield of maleic anhydride is approximately 67 percent. The hot reaction gases are cooled and the crude maleic anhydride is partially condensed. The remaining gases, containing 40-50 percent of the maleic anhydride, are passed through a waste gas scrubber where virtually all of the maleic anhydride is washed out to form a maleic acid solution. The residual gas is flared.

The crude maleic anhydride and the concentrated maleic acid solution exiting from a thin film evaporator are continuously dehydrated in the special dehydrator to yield a relatively pure maleic anhydride and a residue. The dehydrator residue is washed and recycled to the concentrator. The final step taken in purification is to vacuum distill the maleic anhydride to obtain specification grade product, an overhead water condensate, and vacuum column bottoms.

The water condensate from the vacuum still overhead contains 0.0006 kg of maleic anhydride per kg product. The vacuum still bottoms contain in excess of 0.03 kg of moderately dangerous components (12 percent maleic anhydride and 88 percent fumaric acid, chromogenic compounds and tars) per kilogram of product and constitute a hazardous process waste discharge to land.

Lead Alkyls SIC 28692(22, 25, 37-39)

Tetraethyl lead (TEL) production in the United States during 1973 was 160,000 metric tons (353 million pounds).(3) There were 346,000 metric tons of other organo-lead compounds (tetramethyl lead, tetra (methyl-ethyl) lead) produced. Manufacturers reported(4) were E. I. duPont de Nemours and Company, Inc., the Nalco Chemical Company, PPG Industries, Inc., and Ethyl Corporation. The almost exclusive use for these compounds was as motor fuel additives — "anti-knock" fluid for blending with gasoline. Typical lead alkyl production plant sizes ranged from 18,000 to 100,000 metric tons per year.

Generally, some version of the 40-year old original batch process is used to produce TEL from the reaction between ethyl chloride and sodium-lead alloy. Figure 5-18 presents a composite of typical process flows. A 90:10 weight ratio lead:sodium alloy is prepared in an alloy pot and cooled under an atmosphere of nitrogen and then charged to an autoclave. An excess of ethyl chloride is charged to the autoclave reactor, which is equipped with a reflux condenser. The reaction takes place at 520-525 kilonewtons/square meter and 65-70^{o}C. It is as follows:

$$4C_2H_5Cl + 4PbNa \longrightarrow 3Pb + 4NaCl + Pb(C_2H_5)_4 \qquad \text{(TEL)}$$

Waste hydrocarbons produced by side reactions between the sodium and the ethyl chloride are discharged to the atmosphere.

The mixture, after completion of the reaction, is fed to a still, where the TEL is stripped from the lead and sodium chloride. The TEL and water vapor are condensed and sent to a decanter from which the TEL is withdrawn as a bottoms stream. The upper layer containing unreacted ethyl chloride and organic by-products is transported via an open ditch to the next treatment step.

The TEL in the bottoms stream is washed, settled, and blended with ethylene dichloride (EDC), ethylene dibromide (EDB) and dyes prior to storage/shipment as product. The salt-containing sludge bottoms from the still are decanted to separate the bulk of the lead from the solution. The lead sludge is washed free of sodium chloride, dried, and remelted before being recycled for reuse. The salt solution, containing some suspended lead, goes to a sludge pit. The bottoms from the sludge pit are periodically sent to lead recovery. The overflow from the sludge pit is combined with the overflow from the TEL decanter. This stream next has sodium carbonate solution added and ozone bubbled through to precipitate the remaining lead. This lead precipitate is separated in a settling basin; it amounts to 0.1 kg of lead precipitate per kg TEL. It is a highly dangerous process waste discharge (currently recovered in many plants).

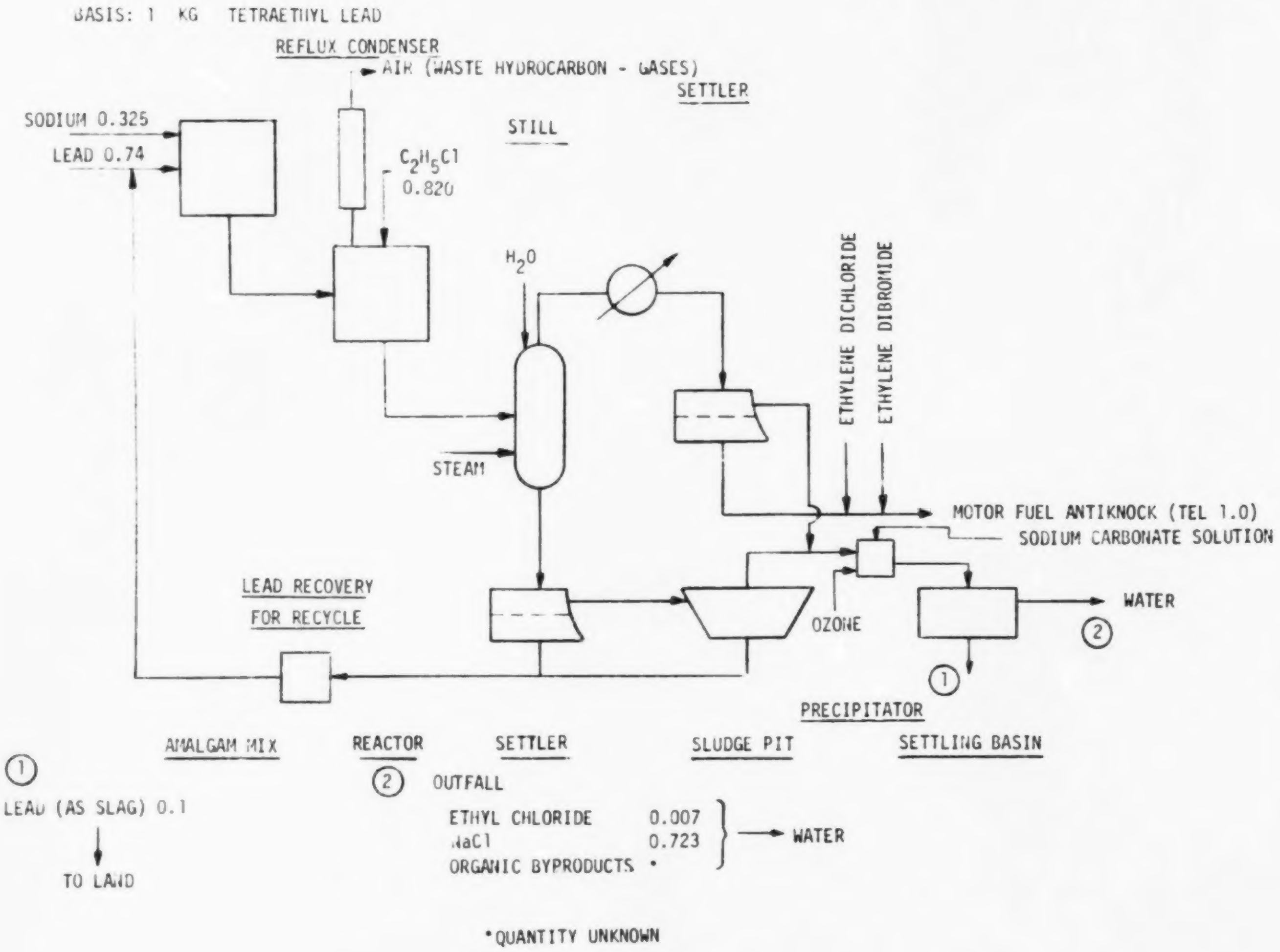

BASIS: 1 KG TETRAETHYL LEAD
REFLUX CONDENSER
AIR (WASTE HYDROCARBON - GASES)
SETTLER
STILL
SODIUM 0.325
LEAD 0.74
C_2H_5Cl 0.820
H_2O
STEAM
ETHYLENE DICHLORIDE
ETHYLENE DIBROMIDE
MOTOR FUEL ANTIKNOCK (TEL 1.0)
SODIUM CARBONATE SOLUTION
LEAD RECOVERY FOR RECYCLE
OZONE
WATER
②
①
PRECIPITATOR
AMALGAM MIX
REACTOR
SETTLER
SLUDGE PIT
SETTLING BASIN
① LEAD (AS SLAG) 0.1
TO LAND
② OUTFALL
ETHYL CHLORIDE 0.007
NaCl 0.723
ORGANIC BYPRODUCTS •
WATER
•QUANTITY UNKNOWN

Figure 5-18. Lead Alkyls Manufacture

The settling basin overflow is discharged to a process outfall. The charge to the outfall has 0.007 kg ethyl chloride per kg TEL product, and an unknown quantity of complex, partially chlorinated organic by-products as its hazardous components. The Federal Water Pollution Control Act Amendments will require the removal of these materials, and their disposal to the land.

α-Chlorotoluene SIC 28651(25, 27)

Total United States production of α-chlorotoluene (benzyl chloride) in 1972 was 36,500 metric tons (80 million pounds).(4) There were only three known manufacturers in 1972: Stauffer Chemical Company (Specialty Products Division), Monsanto Company, and Velsicol Chemical Corporation. Typical process facility sizes are estimated to range in capacity from 10,000 to 15,000 metric tons per year. The material is used as an intermediate for the manufacture of plasticizer (butyl benzyl phthalate) and as a benzylating agent.

Figure 5-19 presents a typical process flow diagram for the manufacture of α-chlorotoluene. Dry chlorine reacts with an excess of refluxing toluene in a glass-lined reactor kettle, as follows:

$$Cl_2 + CH_3C_6H_5 \xrightarrow[110^oC]{} HCl + C_6H_5CH_2Cl \qquad (\alpha\text{-chlorotoluene})$$

The hydrogen chloride produced comes off as an overhead from the condenser and is sent to by-product recovery.

The excess of toluene is removed from the benzyl chloride in a fractionating column and recycled. The undercut, crude benzyl chloride, is distilled to produce the refined product and a bottom cut. The still bottoms are a hazardous process waste discharge to land disposal and contain 0.001 kg of highly dangerous components (benzyl chloride and benzotrichloride) per kg of product benzyl chloride.

Methylene Chloride SIC 28692(20, 25-28)

Methylene chloride (dichloromethane) production in the United States in 1973 was 236,000 metric tons (520 million pounds).(3) There were six major manufacturers: Allied Chemical Corporation (Specialty Chemicals Division), Diamond Shamrock Corporation, Dow Chemical Company, E. I. duPont de

BASIS: 1 KG α - CHLOROTOLUENE (BENZYL CHLORIDE)

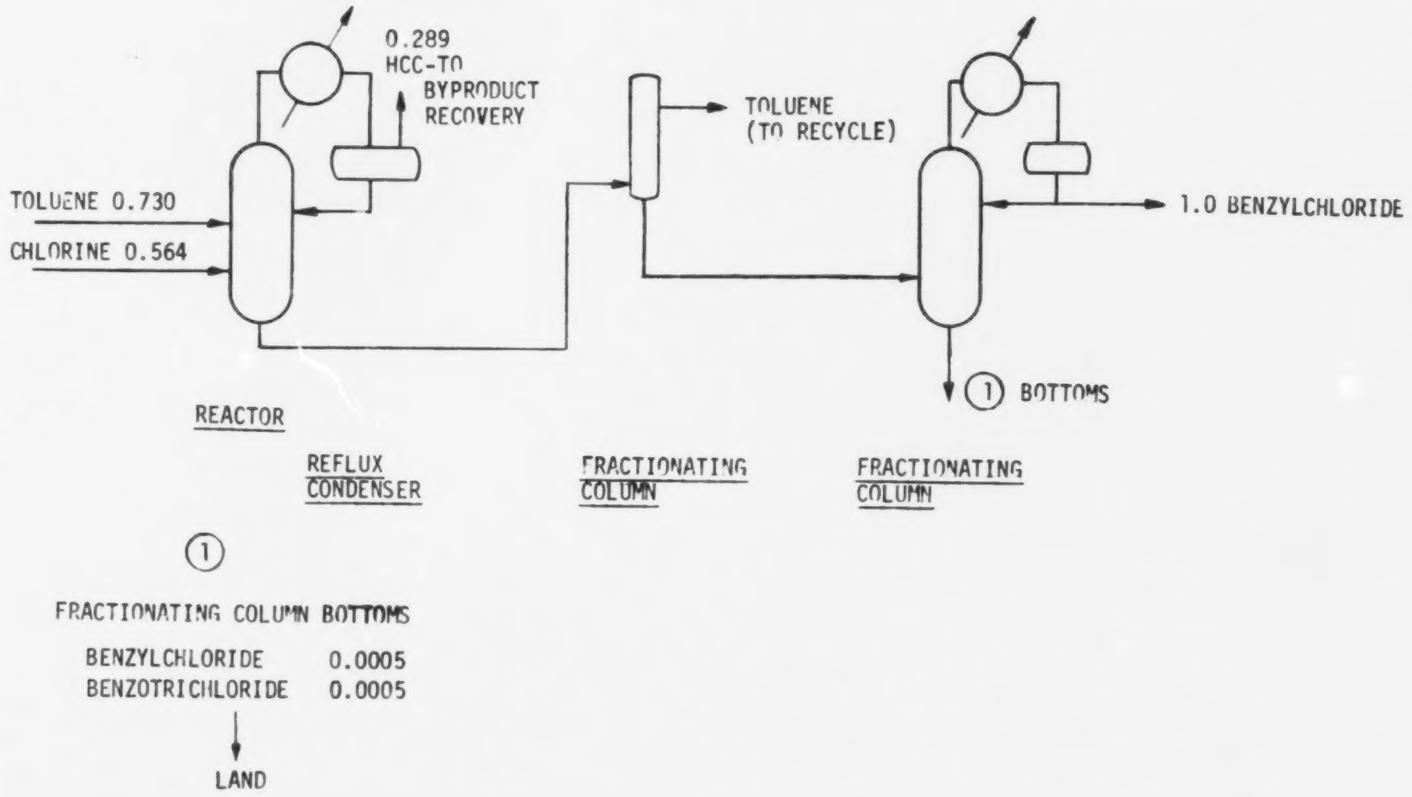

0.289
HCC-TO
BYPRODUCT
RECOVERY
TOLUENE 0.730
CHLORINE 0.564
TOLUENE
(TO RECYCLE)
1.0 BENZYLCHLORIDE
① BOTTOMS
REACTOR
REFLUX
CONDENSER
FRACTIONATING
COLUMN
FRACTIONATING
COLUMN
①
FRACTIONATING COLUMN BOTTOMS
BENZYLCHLORIDE 0.0005
BENZOTRICHLORIDE 0.0005
LAND

Figure 5-19. Chlorotoluene Manufacture

Nemours and Company, Inc., Vulcan Materials Company (Chemical Division), and Stauffer Chemical Company (Industrial Division). Major uses are as a paint remover solvent and aerosol propellant. The typical production facility size is 15,000 metric tons per year.

The major process employed for methylene chloride production is the continuous noncatalytic chlorination of methane-methyl chloride mixture. Figure 5-20 presents a typical process flow diagram. Gaseous methane, chlorine, and a recycled stream of methyl chloride are preheated and fed to a reactor equipped with mercury arc lamps. Residence times in the reactor are controlled to maintain a temperature of 447° to 472°C. All of the chlorine, all of the methyl chloride and about 65 percent of the methane react. The reactions which take place are:

$CH_4 + Cl_2 \longrightarrow HCl + CH_3Cl$ (Methyl chloride)

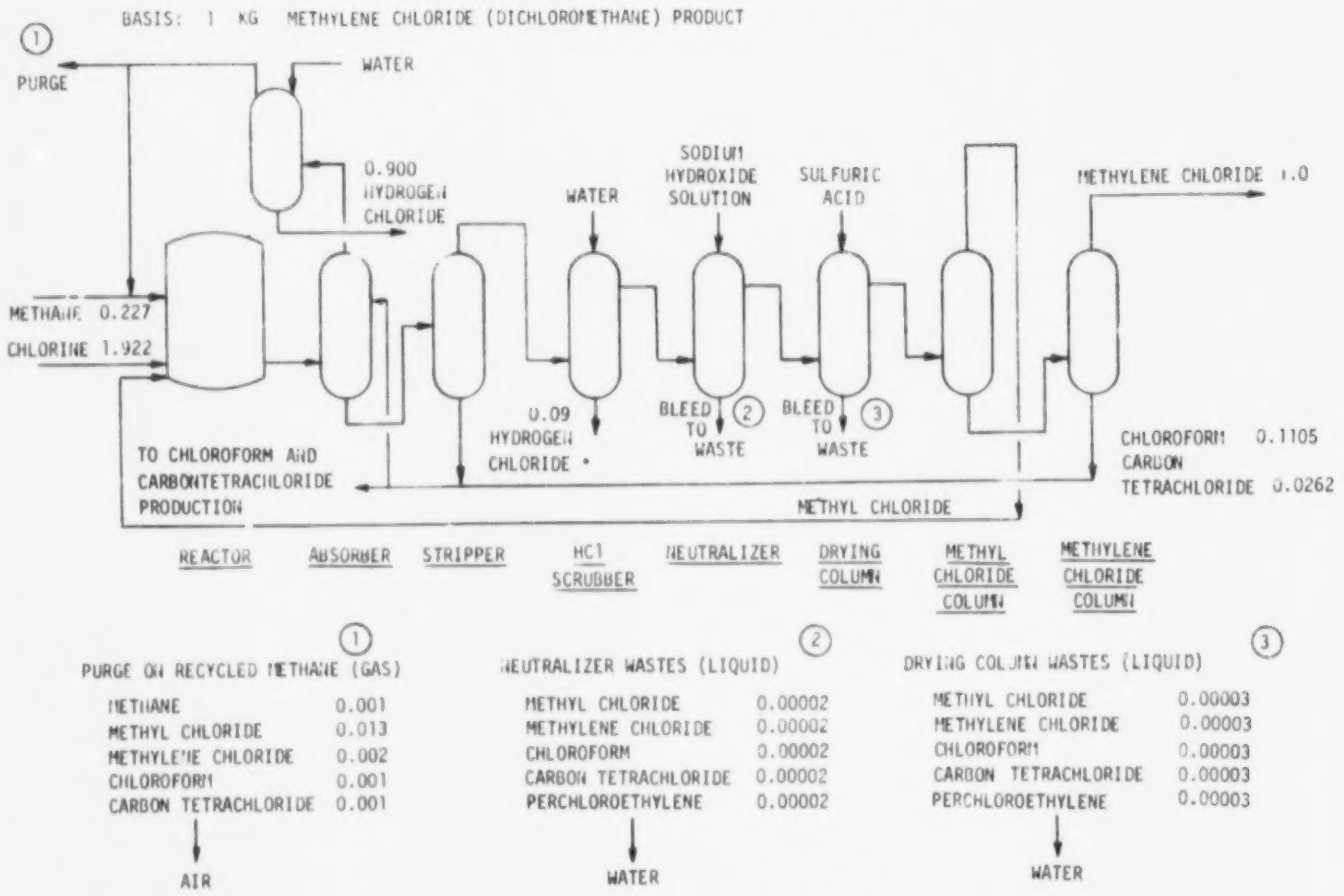
$CH_3Cl + Cl_2 \longrightarrow HCl + CH_2Cl_2$ (Methylene chloride)

$CH_2Cl_2 + Cl_2 \longrightarrow HCl + CHCl_3$ (Chloroform)

$CHCl_3 + Cl_2 \longrightarrow HCl + CCl_4$ (Carbon tetrachloride)

The exit gases from the reactor contain unreacted methane in addition to the chloromethane products shown above. The chloromethanes are separated from the methane and HCl by scrubbing the reactor effluent gases with a mixture of refrigerated liquid chloromethanes whose major constituents are chloroform and carbon tetrachloride. Methane and HCl are discharged as gases and transferred to a water absorber, which produces by-product liquid hydrochloric acid solution. The gaseous methane is not absorbed, and is recycled to the reactor.

The chloromethane absorber liquid effluent is fed to a stripper. The overheads from the stripping column are the methyl chloride and methylene chloride. These are condensed, washed with hot water to remove residual HCl, then washed with alkali solution, and finally dried with concentrated sulfuric acid. Methyl chloride is taken off as the overhead in a fractionation column and recycled. The high boiling fraction is redistilled in an additional column to yield methylene chloride product and chloroform/carbon


BASIS: 1 KG METHYLENE CHLORIDE (DICHLOROMETHANE) PRODUCT
①
PURGE
WATER
0.900
HYDROGEN
CHLORIDE
WATER
SODIUM
HYDROXIDE
SOLUTION
SULFURIC
ACID
METHYLENE CHLORIDE 1.0
METHANE 0.227
CHLORINE 1.922
0.09
HYDROGEN
CHLORIDE *
BLEED TO WASTE ②
BLEED TO WASTE ③
CHLOROFORM 0.1105
CARBON
TETRACHLORIDE 0.0262
TO CHLOROFORM AND
CARBONTETRACHLORIDE
PRODUCTION
METHYL CHLORIDE
REACTOR
ABSORBER
STRIPPER
HCl
SCRUBBER
NEUTRALIZER
DRYING
COLUMN
METHYL
CHLORIDE
COLUMN
METHYLENE
CHLORIDE
COLUMN
①
PURGE ON RECYCLED METHANE (GAS)
METHANE 0.001
METHYL CHLORIDE 0.013
METHYLENE CHLORIDE 0.002
CHLOROFORM 0.001
CARBON TETRACHLORIDE 0.001
AIR
②
NEUTRALIZER WASTES (LIQUID)
METHYL CHLORIDE 0.00002
METHYLENE CHLORIDE 0.00002
CHLOROFORM 0.00002
CARBON TETRACHLORIDE 0.00002
PERCHLOROETHYLENE 0.00002
WATER
③
DRYING COLUMN WASTES (LIQUID)
METHYL CHLORIDE 0.00003
METHYLENE CHLORIDE 0.00003
CHLOROFORM 0.00003
CARBON TETRACHLORIDE 0.00003
PERCHLOROETHYLENE 0.00003
WATER

* HCl CONTENT-32 PERCENT BY WEIGHT IN WATER SOLUTION

Figure 5-20. Methylene Chloride Manufacture

tetrachloride bottoms which are recycled for use as solvent in the absorber or sent to the $CHCl_3$-CCl_4 manufacturing facility.

Process waste discharges include:

- Purge gas to air from the methane recycle system containing, per kilogram of product methylene chloride, 0.001 kg methane, 0.013 kg methyl chloride, 0.002 kg of methylene chloride, 0.001 kg of chloroform, and 0.001 kg of carbon tetrachloride.
- Neutralizer liquid wastes (spent alkali bleed) to the industrial outfall from the alkali wash tower containing, per kg of product methylene chloride, 0.00002 kg each of methyl chloride, methylene chloride, chloroform, carbon tetrachloride and perchloroethylene.
- Drying column liquid wastes (spent drying acid bleed) to the industrial outfall from the drying tower containing, per kg of product methylene chloride, 0.00003 kg each of methyl chloride, methylene chloride, chloroform, carbon tetrachloride and perchloroethylene.

The hydrogen chloride solution coming from the hot water wash tower is stripped of its chloromethane content and used as feed to the HCl absorber.

There are no process wastes to land disposal. The Federal Water Pollution Control Act Amendments will require removal of the chlorinated hydrocarbons currently present in the liquid wastes sent to the industrial outfall.

1,1,1-Trichloroethane SIC 28692(20, 22)

Production of 1,1,1-trichloroethane (methylchloroform) in 1973 was just under 250,000 metric tons (548 million pounds). Major producers were the Dow Chemical Company, Vulcan Materials Company (Chemical Division), PPG Industries, Inc., and Ethyl Corporation. A typical process line capacity is 18,000 metric tons (40 million pounds) per year.

Figure 5-21 presents a typical process flow diagram for the production of 1,1,1-trichloroethane from vinyl chloride and chlorine. The process emits no hazardous wastes to land, currently. Vinyl chloride, make-up and recycled hydrogen chloride, recycled dichloroethane and recycled

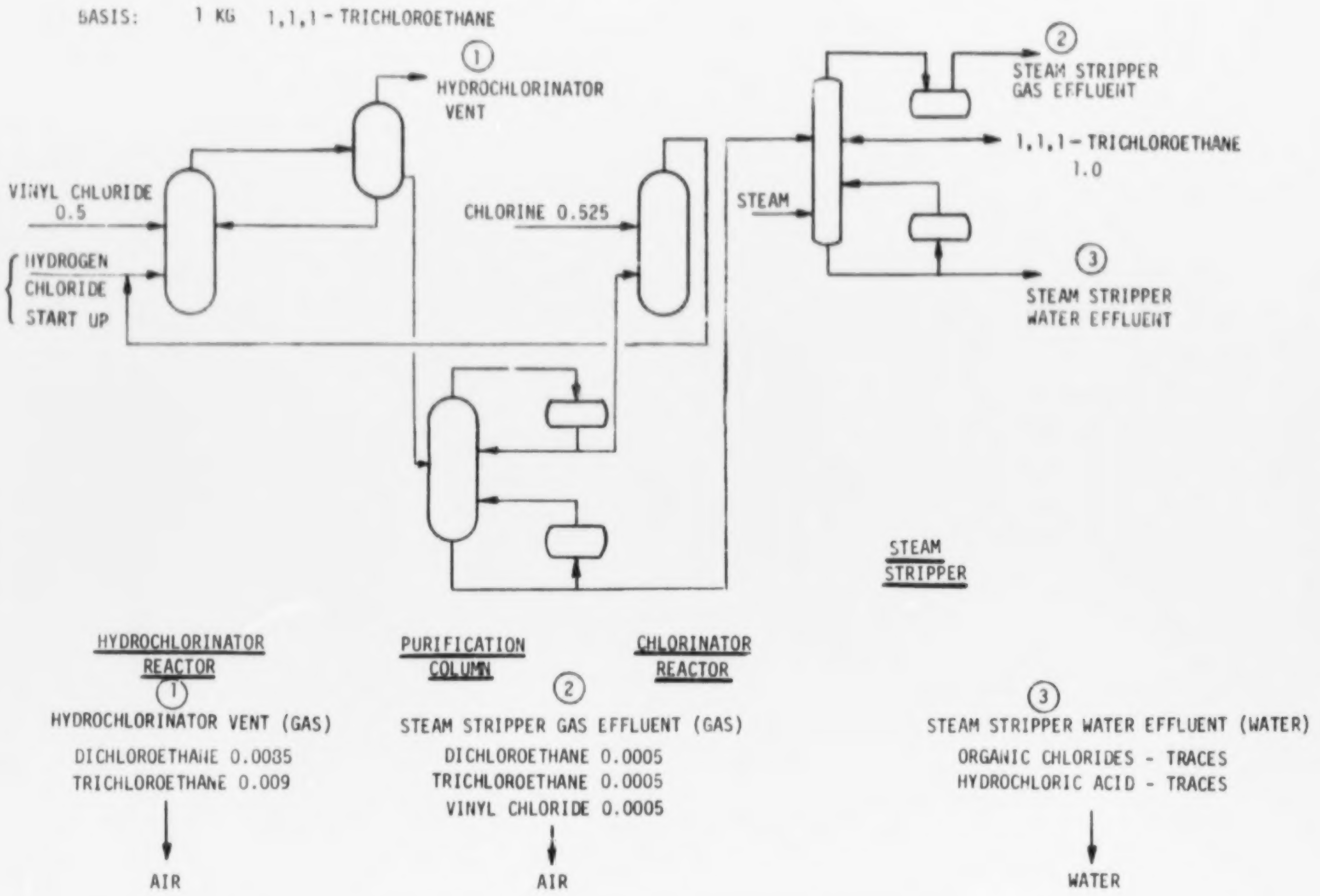

BASIS: 1 KG 1,1,1-TRICHLOROETHANE
①
HYDROCHLORINATOR VENT
VINYL CHLORIDE 0.5
HYDROGEN CHLORIDE START UP
CHLORINE 0.525
STEAM
②
STEAM STRIPPER GAS EFFLUENT
1,1,1-TRICHLOROETHANE 1.0
③
STEAM STRIPPER WATER EFFLUENT
STEAM STRIPPER
HYDROCHLORINATOR REACTOR
PURIFICATION COLUMN
CHLORINATOR REACTOR
①
HYDROCHLORINATOR VENT (GAS)
DICHLOROETHANE 0.0035
TRICHLOROETHANE 0.009
AIR
②
STEAM STRIPPER GAS EFFLUENT (GAS)
DICHLOROETHANE 0.0005
TRICHLOROETHANE 0.0005
VINYL CHLORIDE 0.0005
AIR
③
STEAM STRIPPER WATER EFFLUENT (WATER)
ORGANIC CHLORIDES - TRACES
HYDROCHLORIC ACID - TRACES
WATER

Figure 5-21. 1,1,1-Trichloroethane Manufacture trichloroethane are fed to a tower reactor for the catalyzed hydrochlorination reaction which produces the dichloroethane intermediate:

$$HCl + CH_2{=}CHCl \xrightarrow[35\text{-}40^{o}C]{FeCl_3} C_2H_4Cl_2 \qquad \text{(Dichloroethane)}$$

The dichloroethane cut is taken overhead from the purification column, and chlorinated in the chlorinator reactor:

$$Cl_2 + C_2H_4Cl_2 \xrightarrow[400^{o}C]{} CH_3CCl_3 + HCl \qquad \text{(1,1,1-Trichloroethane)}$$

The crude trichloroethane, the hydrogen chloride produced, and the excess dichloroethane are recycled to the hydrochlorination reactor. Product crude trichloroethane is taken as the high boiling fraction from the purification column, steam stripped, and distilled to produce 1,1,1-trichloroethane for storage and sales.

5.2.2 Annual Process Stream Discharge to Land Disposal

The estimated total quantities (dry weight basis) of process waste streams generated and discharged to land-based disposal in calendar year 1973 for those portions of the organic chemical industry covered in this study are presented in Table 5-1 by Standard Industrial Classification product group for each state. Land-based disposal, as used herein, covers landfill, land burial, deep-well disposal, deep-sea disposal, lagooning and incineration.

The estimated national total quantity (dry weight basis) of process waste streams discharged to land-based disposal in 1973 by organic chemical plants was 2.18 million metric tons.* The majority of these process waste streams were low in water content or were nonaqueous, based on the sample of the industry described in Section 6.2. Based on this sample, the high-water-content process waste streams which went to deep wells, lagoons, and evaporation ponds constituted only 13 percent of the number of waste streams sent to land disposal by the organic chemicals industry. The water content of the wastes sent to deep wells, lagoons, and evaporation ponds

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*Includes wastes from technical organic pest control chemical plants, and thus differs from the figures presented in the Executive Summary.

Table 5-1. Total Process Waste Stream* Discharge to Land Disposal, Metric Tons for CY 1973 by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3217		325	12847	51		330		544		35,152		[illegible]
10	Alaska													
9	Arizona													
6	Arkansas											3492		3,492
9	California				1731	11	7	46	2	7978		16757		26,478
8	Colorado				14							794		808
1	Connecticut										815	842		1,657
3	Delaware				22200									22,200
3	District of Columbia													
4	Florida	2275	6214	163					788	17394		93		26,927
4	Georgia		465	2213				100	197	5734		469		9,178
9	Hawaii													
10	Idaho													
5	Illinois				9509			167	2	1474	749	5395		17,296
5	Indiana							183		604		190		977
7	Iowa											4,245		4,245
7	Kansas				1295					179		1524		2,998
4	Kentucky				13	10	3			95246				95,262
6	Louisiana		295	325	83413				136	160232	[illegible]	22729		267,135
1	Maine													
3	Maryland				565	11		417				255		1,248
1	Massachusetts				8	101	9							118
5	Michigan				16776	4	7	143	337	2689	[illegible]	7514		[illegible]
5	Minnesota							46				90		136
4	Mississippi				1788				197			7014		[illegible]
7	Missouri				4789					6830	12	6911		[illegible]
8	Montana													
7	Nebraska													
9	Nevada													
1	New Hampshire													
2	New Jersey				37094	1571	217	46	1912	5991	503	19647		66,382
6	New Mexico													
2	New York				69	538	45		98	2808	1591	1151		[illegible]
4	North Carolina				27700	438	47					109		28,294
8	North Dakota													
5	Ohio				1160	115	12	739	342	10508	116	1772		14,764
6	Oklahoma													
10	Oregon							46				1524		1,570
3	Pennsylvania				22970	193	9	269		88370	89	407		[illegible]
2	Puerto Rico				7349					3597			122	[illegible]
1	Rhode Island					27	3		5					35
4	South Carolina				22211	138						146		22,495
8	South Dakota													
4	Tennessee				29600	6		16	1023	173849		5871		[illegible]
6	Texas				167471			12606		219800	940	10647		[illegible]
8	Utah				157			71						[illegible]
1	Vermont													
3	Virginia				3634	7				12		16		3,669
10	Washington				2963							1389		[illegible]
3	West Virginia				9037	34	46	46	1559	171764	746			[illegible]
5	Wisconsin											[illegible]		[illegible]
8	Wyoming													
NATIONAL TOTALS		5493	6994	1026	483611	3287	401	15,557	[illegible]	1,478,565	5620	[illegible]	122	[illegible]

REGION TOTALS	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	
1				8	128	12		5		815	842		[illegible]
2				44512	2109	262	46	2050	12396	2194	20740	122	[illegible]
3				56400	245	55	752	1559	260156	791	602		[illegible]
4	5493	6679	2701	93476	639	50	506	2205	292769		41194		[illegible]
5				27445	115	15	1478	721	15275	867	20129		[illegible]
6		295	325	250884			12606	136	[illegible]	945	[illegible]		[illegible]
7				4044					7009	12	12700		[illegible]
8				[illegible]		7	77				798		[illegible]
9				1731	11		46	2	7978		16753		[illegible]
10				2963			46				3977		[illegible]

*Estimated water-free basis, using the procedures given in Section 3 and Appendix B. The data for the calculations were obtained from private industry sources listed in Table A-1 and References 3, 4, 8, 11, 12, 19-49.

was very high – so high that it raised the ratio between actual tons (wet basis) and dry basis tons for the entire sample to 3.17. Calculated on the basis of this ratio, the estimate of the wet-basis weight of the process waste streams sent to land in 1973 by the organic chemicals industry was 6.9* million metric tons. Analogous estimates of the process wastes which will be sent to land by the industry in 1977 and 1983 were 11.1* and 12.2* million metric tons, respectively.

Dry weight of the process waste streams has been used as the basis of the estimates presented below for the organic chemicals industry.

The major industry product groups which discharge the highest quantities of process waste streams to the land nationally are:

- SIC 28692, the miscellaneous acyclic chemicals and chemical products group of the industrial organic chemicals industry, with just under 1.5 million metric tons
- SIC 28651, the cyclic intermediates product group of the cyclic crudes and intermediates industry, with approximately 0.5 million metric tons
- SIC 28694 (also covered in Section 5.3), the pesticides and other synthetic organic agricultural chemicals product group of the industrial organic chemicals NEC industry, estimated at slightly less than 0.2 million metric tons.

SIC 28692 and SIC 28651 combined account for approximately 90 percent of the total estimate of wastes destined for land disposal from the organic chemicals industry. These two product groups are, as shown in Table 4-4, the bellwethers of the industry in production with over 92 percent of the industry's total. Product group total waste generation factor weighted averages** are 0.024 kg of process waste to land per kg of production for SIC 28692, and 0.031 kg of process waste to land per kg of production for SIC 28651; the industry-wide factor is 0.026.

The states which have the highest total estimated process waste discharge to land are Texas, Tennessee, and West Virginia for SIC 28692, and

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*Includes wastes from technical organic pest control chemical plants, and thus differs from the figures presented in the Executive Summary.

**Obtained by dividing the estimated total dry-basis process weight discharge to land for the product group by the estimated total production rate for the product group (from Table 4-4).

Texas, Louisiana and New Jersey for SIC 28651. Texas, with its tremendous concentration of organic chemical industry manufacturing, has almost one-half of the total national process waste discharge to land for SIC 28692 and one-third of the national figure for SIC 28651.

The projections for total process waste discharge to land by the organic chemicals industry in 1977 and 1983 are presented in Tables 5-2 and 5-3. The estimated total process waste discharged to land for the industry in 1977 goes up by over 67 percent from the 1973 figure. The average total waste generation factor for the industry rises to 0.039 kg of process waste per kg of production in 1977. The reason for this increase in the estimated waste discharge to land is the impact projected for the Federal Water Pollution Control Act Amendments.

Roughly 90 percent of the increase in the "water-free basis" weight of total process waste stream discharges to land* for the industry is a result of the following assumption: Land disposal processes will be implemented in 1977 for those hazardous wastes currently discharged to water whose presence in industrial outfalls will not be permitted in 1983 by the Federal Water Pollution Control Act as amended. This is, of course, a worst-case assumption for 1977; most probably the actual figures will be somewhere between the least impact assumption of only a 10 percent increase (based on increased production), and the worst-case assumption. There was no basis available for determining a more realistic number at the time of this study.

The figures for 1983 reflect the impact of the legal requirements as amended for 1983, and the much lesser impact of a 21.6 percent increase in production. The estimated total "dry weight" process waste discharge to land for the industry in 1983 is 3.9 million tons. The associated process waste discharge factor is 0.038 kg of waste per kg of production; the increase here reflects strictly the assumed impact of the enforced removal of hazardous materials from industrial outfalls.

The manufacture of the SIC 28692 and SIC 28651 product groups will still provide over 90 percent of the total industry process waste discharged

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*As defined for this study, "discharge to the land" includes landfill, land burial, deep-well disposal, lagooning, and incineration.

Table 5-2. Total Process Waste Stream* Discharge to Land Disposal, Metric Tons for CY 1977 by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3529		358	27453	54		370	133	1462		[illegible]		76,037
10	Alaska									22				22
9	Arizona													
6	Arkansas									1454		3841		5,295
9	California				6445	12	2	51	190	41161	16	10591		58,473
8	Colorado				32							978		1,010
1	Connecticut				210						925	1247		2,382
3	Delaware				25278					1888				27,166
3	District of Columbia													
4	Florida	2503	6836	179					870	20866		122		31,376
4	Georgia		533	2434				110	217	7741		500		11,535
9	Hawaii													
10	Idaho													
5	Illinois				19329			164	161	17125	905	5852	10869	54,475
5	Indiana				345			201		6529	42	211		7,328
7	Iowa									1895		5849		7,744
7	Kansas				2864					826		1676		5,375
4	Kentucky				663	11	3			122442				123,119
6	Louisiana		325	358	97532				755	743826	548	26435		869,779
1	Maine													
3	Maryland				1900	11		459		7		363		2,740
1	Massachusetts				0.9	137	10			1812	28			1,988
	Michigan				21535	0.4	1	636		1770	37	4423		28,402
	Minnesota							51				191		242
4	Mississippi				1751				217	671	46	11843		[illegible]
7	Missouri				1046					4690	175	8132		[illegible]
8	Montana									447				447
7	Nebraska													
9	Nevada				335									335
1	New Hampshire								129					129
2	New Jersey				82675	3670	234	312	2873	20816	1780	25662	3	[illegible]
6	New Mexico													
2	New York				646	563	49	212	362	[illegible]	1819	1816		[illegible]
4	North Carolina				33905	467	57		521	4247	167	153		[illegible]
8	North Dakota													
5	Ohio				1637	122	18	1337	605	37277	306	2871		[illegible]
6	Oklahoma									189				189
10	Oregon							51		3560		1576		[illegible]
3	Pennsylvania				42171	205	12	916		102876	575	527	5646	[illegible]
2	Puerto Rico				20612					92864			135	[illegible]
1	Rhode Island					29	3		5		592			[illegible]
4	South Carolina				24439	186				1814		[illegible]		[illegible]
8	South Dakota													
4	Tennessee				32711	7		85	3544	216059	341	2395		[illegible]
6	Texas				206084			14663	295	[illegible]	775	[illegible]	9557	[illegible]
8	Utah				358			85						443
1	Vermont													
3	Virginia				5826	7				314		76		6,223
10	Washington				4904					[illegible]		2044	373	[illegible]
3	West Virginia				17284	27	49	767	1829	[illegible]	850			[illegible]
5	Wisconsin				625					1671		5761		[illegible]
8	Wyoming													
NATIONAL TOTALS		6042	7694	[illegible]	665,074	1,443	437	[illegible]	9,699	[illegible]	10,9[illegible]	[illegible]	[illegible]	[illegible]

REGION TOTALS													
1				211	136	13		134	1662	1546	1247		5,449
2				83933	2233	283	524	2835	[illegible]	3599	26449	[illegible]	[illegible]
3				92459	260	12	2184	1929	113148	1426	918	[illegible]	[illegible]
4	6042	7369	2971	122002	680	14	565	3500	381334	1162	83394		[illegible]
5				43671	122	21	2409	766	66896	1291	23806	10869	[illegible]
6		325	358	305616			14663	144	1504306	1324	55126	9557	[illegible]
7				3910					15011	675	17076		38,568
8				378			85		447		978		[illegible]
9				6780	12	2	51	190	41161	16	10591		[illegible]
10				4904			51		[illegible]		[illegible]	373	[illegible]

*Estimated, water-free basis, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3, 4, 8, 11, 22, 39-51.

Table 5-3. Total Process Waste Stream* Discharge to Land Disposal, Metric Tons for CY 1983 by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3912		196	10389	58		409	137	1616		42162		84,049
10	Alaska									65				85
9	Arizona													
6	Arkansas									1600		6246		5,854
9	California				7125	12	8	56	210	49501	18	20556		77,486
8	Colorado				36							1061		[illegible]
1	Connecticut				232						1023	1376		2,631
3	Delaware				27943					2087				30,030
3	District of Columbia													
4	Florida	2767	7556	198					959	22069		135		34,694
4	Georgia		589	[illegible]				723	741	10769		552		14,967
9	Hawaii													
10	Idaho													
5	Illinois				21367			213	176	1094	1006	6580	11249	90,279
5	Indiana				361			222		2137	46	222		8,107
7	Iowa									1653		[illegible]		2,567
7	Kansas				1106					924		1653		3,443
4	Kentucky				732	12	3			140261				[illegible]
6	Louisiana		359	196	102617				166	100739	607	20712		[illegible]
1	Maine													
3	Maryland				2201	12		507		9		799		[illegible]
1	Massachusetts				1	118	16			1637	31			3,993
5	Michigan				11005	4	3	113	409	5264	46	4531		19,177
5	Minnesota							56				211		267
4	Mississippi				3041				240	741	576	11649		[illegible]
7	Missouri				1307					9596	135			
8	Montana									494				494
7	Nebraska													
9	Nevada				170									[illegible]
1	New Hampshire								141					141
2	New Jersey				68264	1783	250	174	[illegible]	23012	1990	[illegible]	4	[illegible]
6	New Mexico													
2	New York				714	[illegible]	52	787	400	7772	1011	1567		[illegible]
4	North Carolina				17569	494	54		576	4695	181	176		51,144
8	North Dakota													
5	Ohio				1909	131	19	1219	[illegible]	41760	178	[illegible]		[illegible]
6	Oklahoma									209				209
10	Oregon							14		6147		1853		[illegible]
3	Pennsylvania				46615	279	10	[illegible]		113996	628	582	6180	[illegible]
2	Puerto Rico				23298					103215			142	[illegible]
1	Rhode Island					31	3		9		655			690
4	South Carolina				27216	156				1563		244		29,477
8	South Dakota													
4	Tennessee				36160	7		31	[illegible]	238676	580	[illegible]		[illegible]
6	Texas				230029			[illegible]	326	[illegible]	357	2790	6695	[illegible]
8	Utah				394			43	4					441
1	Vermont													
3	Virginia				6440	8				402		29		6,879
10	Washington				5471					685		1143	412	[illegible]
3	West Virginia				19106	19	53	345	2502	224727	341			[illegible]
5	Wisconsin				912					741		5299		[illegible]
8	Wyoming													
NATIONAL TOTALS		6679	8504	[illegible]	[illegible]	3041	461	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REGION TOTALS													
1				233	185	13		182	1637	1200	1376	0	[illegible]
2				92784	2392	302	411	3133	132,999	6001	29233	152	255,414
3				135,288	278	63	2370	2977	186,170	1577	3211	4180	[illegible]
4	6679	8145	3294	138,867	727	57	623	1869	422,709	1211	75,794	0	[illegible]
5				48274	131	22	2662	1255	71,947	1426	25,876	11,949	[illegible]
6		359	396	337,845			16,231	492	[illegible]	1464	46,933	5695	[illegible]
7				6533					12,171	630	10080		[illegible]
8				430			43	4	494		1081		[illegible]
9				7895		8	56	210	49501	18	20556		[illegible]
10				5471	12		56	0	6917		4997	412	[illegible]

*Estimated, water-free basis, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 1, 4, 8, 11, 12, 19-51.

to land in 1977 and 1983. Texas, Louisiana and Tennessee are the states with the highest total process waste discharge to land in 1977 and 1983 for SIC 28692. For SIC 28651, Texas, Louisiana and New Jersey are projected to be the states with the highest total process waste discharge to land in 1977 and 1983.

The data on estimated total process discharge by the organic chemicals industry to land disposal for hazardous waste streams are presented in Tables 5-4, 5-5 and 5-6 for calendar years 1973, 1977 and 1983, respectively. It will be noted that waste streams rated as hazardous account for almost 98 percent of total process waste discharges to land. The relative quantities of wastes for the SIC product groups remain the same – SIC 28692 first, at just under 1.5 million metric tons, SIC 28651 second, at just under 0.5 million metric tons, and SIC 28694 third, at just under 0.2 million metric tons. Similarly, in SIC 28692 the greatest quantities of total hazardous waste stream discharges will be in the states of Texas, Tennessee and West Virginia in 1973, and Texas, Louisiana and Tennessee in 1977 and 1983. For SIC 28651 the states discharging the greatest quantities of hazardous waste streams to land are unchanged – Texas, Louisiana and New Jersey for all 3 years for which estimates were made.

The hazardous component contents, in metric tons, of the process waste streams discharged to the land by the organic chemicals industry in calendar years 1973, 1977 and 1983 are presented in Tables 5-7, 5-8 and 5-9, respectively. The product group with the greatest quantity of hazardous components in 1973 was SIC 28651, the cyclic intermediates, with slightly over 0.4 million metric tons; SIC 28692 was second with 0.3 million metric tons; and SIC 28694 was third with under 60,000 metric tons. The hazardous component content discharge factors* were 0.027 kg per kg of product for SIC 28651, 0.0048 kg per kg of product for SIC 28692, and 0.010 kg per kg of product for the industry as a whole. The two high hazardous component discharge product groups (SIC 28651 and SIC 28692) account for 88 percent of the industry's total.

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*Obtained by dividing the estimated total hazardous component content for the product group by the estimated total production rate for the product group (from Table 4-4).

Table 5-4. Total Process Discharge to Land Disposal[1], Hazardous Waste Streams[2] Metric Tons for CY 1973 by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3217		325	12667	51		330		544		35153		52,287
10	Alaska													
9	Arizona													
6	Arkansas											3492		3,492
9	California				1731	11	7	46	2	7928		16753		26,478
8	Colorado				14							794		808
1	Connecticut										815	842		1,657
3	Delaware				22200									22,200
3	District of Columbia													
4	Florida	2275	6214	163					788	17165		93		26,698
4	Georgia		485	2213				100	197	5734		449		9,178
9	Hawaii													
10	Idaho													
5	Illinois				9509			167	2	1046	749	5395		16,868
5	Indiana							183		336		190		709
7	Iowa											4245		4,245
7	Kansas				1295					179		1524		2,998
4	Kentucky				113	10	3			94311				[illegible]
6	Louisiana		295	325	83413				136	158869	5	22729		265,772
1	Maine													
3	Maryland				565	11		417				255		1,248
1	Massachusetts				8	101	9							118
5	Michigan				16776	4	3	343	337	8601	2	1514		27,576
5	Minnesota							46				90		136
4	Mississippi				1288				197			2012		3,497
7	Missouri				2789					117	12	6031		8,949
8	Montana													
7	Nebraska													
9	Nevada													
1	New Hampshire													
2	New Jersey				27094	1571	217	46	1912	[illegible]	503	10765		[illegible]
6	New Mexico													
2	New York				69	538	45	[illegible]	[illegible]	1808	1691	1151		[illegible]
4	North Carolina				27709	434	47					109		28,299
8	North Dakota													
5	Ohio				1160	115	12	720	382	6312	116	[illegible]		[illegible]
6	Oklahoma													
10	Oregon							46				1524		1,570
3	Pennsylvania				22970	193	4	269		85021	49	400		[illegible]
2	Puerto Rico				7349					8597			122	16,068
1	Rhode Island					27	3		5					35
4	South Carolina				22211	138						146		22,495
8	South Dakota													
4	Tennessee				29600	6		76	1023	174849		6432		[illegible]
6	Texas				167171			12606		707080	940	[illegible]		[illegible]
8	Utah				151			77						228
1	Vermont													
3	Virginia				3634	7						18		3,659
10	Washington				2963							2449		5,412
3	West Virginia				9031	34	46	46	1559	170830	246			[illegible]
5	Wisconsin											567		567
8	Wyoming													
NATIONAL TOTALS		5492	6994	3026	483,621	3247	401	35834	6678	1444482	5678	[illegible]	122	[illegible]

REGION TOTALS													
1				8	128	12		5		815	842		1,802
2				44512	2109	262	347	2000	12960	2194	11920	122	76,426
3				58401	245	55	752	1569	255451	795	680		317,938
4	5492	6699	2701	93475	639	50	506	3205	291603		49394		452,764
5				27345	0.4	15	1459	721	10295	867	15408		[illegible]
6		295	325	250584			12606	136	865949	945	40689		[illegible]
7				4044					296	12	12200		[illegible]
8				165	115		77				794		1,151
9				1731	11		46	2	7928		16753		26,478
10				2963		7	46				3973		[illegible]

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[1] Estimated, water-free basis, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3, [illegible] 11, 12, 19-64.

[2] Defined as process waste streams containing one or more components classified as "Moderately Dangerous" or "Highly Dangerous" in this study.

Table 5-5. Total Process Discharge to Land Disposal, Hazardous Waste Streams, Metric Tons for CY 1977 by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3539		358	27453	54		370	133	1462		47668		76,037
10	Alaska									77				77
9	Arizona													
6	Arkansas									1454		3841		5,295
9	California				6345	12	7	51	190	41161	16	18591		66,473
8	Colorado				32							978		1,010
1	Connecticut				210						925	1247		2,382
3	Delaware				25278					1888				27,166
3	District of Columbia													
4	Florida	2503	6836	179					868	20616		122		31,124
4	Georgia		533	2434				110	217	9741		500		13,535
9	Hawaii													
10	Idaho													
5	Illinois				19329			184	161	16664	905	5952	10809	54,004
5	Indiana				145			201		6735	43	211		7,335
7	Iowa									1495		6249		7,744
7	Kansas				2864					836		1676		5,376
4	Kentucky				663	11	3			126412				127,089
6	Louisiana		325	358	97532				150	342327	549	26036		467,277
1	Maine													
3	Maryland				1900	11		459		7		361		2,738
1	Massachusetts				0.9	107	10			1662	28			1,808
5	Michigan				21535	[illegible]	1	636		4484	37	8871		[illegible]
5	Minnesota							51				191		[illegible]
4	Mississippi				7751				217	671	467	[illegible]		[illegible]
7	Missouri				3046					1796	[illegible]	9151		[illegible]
8	Montana									447				447
7	Nebraska													
9	Nevada				335									335
1	New Hampshire								129					129
2	New Jersey				62675	1570	234	312	2473	15938	1780	15181	3	100,166
6	New Mexico													
2	New York				646	163	49	212	362	7030	1814	3418		12,594
4	North Carolina				33985	462	51		421	4147	167	359		39,592
8	North Dakota													
5	Ohio				1637	177	18	1316	605	13167	306	2671		19,897
6	Oklahoma									169				169
10	Oregon							51		5560		1676		7,287
3	Pennsylvania				42171	705	10	418		99784	575	527	5591	149,[illegible]
2	Puerto Rico				20612					92464			135	113,211
1	Rhode Island					29	3		5		593			630
4	South Carolina				24439	146				1414		221		26,220
8	South Dakota													
4	Tennessee				30711	4		35	1544	216089	578	9499		[illegible]
6	Texas				208084			14683	295	1229745	775	20807	6057	[illegible]
8	Utah				356			85						441
1	Vermont													
3	Virginia				5826	7				353		26		6,212
10	Washington				4904					620		2844	373	8,741
3	West Virginia				17284	37	49	761	1329	206,141	[illegible]			[illegible]
5	Wisconsin				875					671		656		2,202
8	Wyoming													
NATIONAL TOTALS		6042	7694	3,329	665,674	3,443	437	20,791	9,659	2,438,642	10,9[illegible]	192,404	22,460	3,41[illegible],250

REGION TOTALS													
1				211	136	13		134	1662	1546	1247		4,949
2				83933	2233	283	322	2835	115434	3594	16692	138	225,970
3				92359	760	59	2144	1329	307973	1426	914	5591	412,655
4	6042	7369	2,971	122002	680	54	565	3500	380652	1160	63594		588,589
5				43671	122	21	2388	766	61216	1291	18334	10809	[illegible]
6		325	358	305616			14683	445	1573215	1324	50479	6057	[illegible]
7				5910					3627	570	17078		27,185
8				388			35		447		978		1,898
9				6780	12	7	51	190	41161	16	18591		66,808
10				4904			51		6257		4520	373	16,105

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[1] Estimated, water-free basis, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table 4-1 and References 3, 4, 8, 11, 12, 19-54.

[2] Defined as process waste streams containing one or more components classified as "Moderately Dangerous" or "Highly Dangerous" in this study.

Table 5-6. Total Process Discharge to Land Disposal,[1] Hazardous Waste Streams,[2] Metric Tons for CY 1983 by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3912		396	30349	58		409	147	1616		47162		84,049
10	Alaska									85				85
9	Arizona													
6	Arkansas									1608		4246		5,854
9	California				7125	12	8	56	210	45501	18	20551		73,481
8	Colorado				36							1081		1,117
1	Connecticut				232						1023	1378		2,633
3	Delaware				27943					2087				30,030
3	District of Columbia													
4	Florida	2767	7556	198					959	22790		135		34,405
4	Georgia		589	2690				121	240	10768		553		14,961
9	Hawaii													
10	Idaho													
5	Illinois				21367			203	178	18422	1000	6580	11949	59,699
5	Indiana				381			222		6892	48	233		7,776
7	Iowa									1653		6908		8,561
7	Kansas				3166					924		1853		5,943
4	Kentucky				732	12	3			139742				140,489
6	Louisiana		359	396	107817				166	378427	607	28782		516,554
1	Maine													
3	Maryland				2101	12		507		8		377		3,005
1	Massachusetts				1	114	10			1837	31			1,993
5	Michigan				23805	4	3	703	409	4957	40	9531		39,452
5	Minnesota							56				211		267
4	Mississippi				3041				240	741	516	11524		16,062
7	Missouri				3367					1433	630	10119		15,549
8	Montana									494				494
7	Nebraska													
9	Nevada				370									370
1	New Hampshire								142					142
2	New Jersey				69284	1785	250	124	2733	17618	1990	16893	4	110,681
6	New Mexico													
2	New York				714	613	52	787	400	7772	2011	1567		13,916
4	North Carolina				37569	494	54		576	4695	185	176		43,749
8	North Dakota													
5	Ohio				1809	131	19	1455	668	36658	338	2952		44,030
6	Oklahoma									209				209
10	Oregon							56		6147		1853		8,056
3	Pennsylvania				46618	219	10	1015		109864	636	583	6180	165,125
2	Puerto Rico				22786					102215			149	125,150
1	Rhode Island					31	3		6		655			695
4	South Carolina				27016	156				1563		244		28,979
8	South Dakota													
4	Tennessee				36160	7		93	1707	238876	582	10500		287,925
6	Texas				230028			16231	326	1358874	857	22775	6695	1,635,786
8	Utah				394			93	4					491
1	Vermont													
3	Virginia				6440	8				390		29		6,867
10	Washington				5421					685		3144	412	9,662
3	West Virginia				19106	39	53	848	2022	228100	941			251,109
5	Wisconsin				912					741		726		2,379
8	Wyoming													
NATIONAL TOTALS		6679	8504	3680	736090	3695	465	22979	11133	2754392	12108	212666	25389	3,797,78

REGION TOTALS												
1				233	145	13		148	1837	1709	1378	[illegible]	5,463
2				92784	2398	302	911	3133	127605	4001	18460	153	249,747
3				102208	278	63	2370	2022	340449	1577	989	6180	456,136
4	6679	8145	3284	134867	[illegible]	57	623	3869	420791	1283	70294		650,619
5				48274	135	22	2639	1255	67670	1426	20233	11949	153,603
6		359	396	337845			16231	492	1739118	1464	55803	6695	2,158,403
7				6533					4010	630	18880		30,053
8				430			93	4	494		1081		2,102
9				7495	12	8	56	210	45501	18	20551		73,851
10				5421			56		6917		4997	412	17,803

[1] Estimated, water-free basis, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3, 4, 8, 11, 12, 19-54.

[2] Defined as process waste streams containing one or more components classified as "Moderately Dangerous" or "Highly Dangerous" in this study.

Table 5-7. Hazardous Component Content*, Process Waste Stream Discharge to Land Disposal, Metric Tons for CY 1973 by Standard Industrial Classification – Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3217		325	12648	41		330		544		11546		[illegible]
10	Alaska													
9	Arizona													
6	Arkansas											664		664
9	California				1731	8	6	46	[illegible]	[illegible]		[illegible]		[illegible]
8	Colorado				14							[illegible]		[illegible]
1	Connecticut										[illegible]	[illegible]		[illegible]
3	Delaware				22200									[illegible]
3	District of Columbia													
4	Florida	2275	6214	163					[illegible]	[illegible]		[illegible]		[illegible]
4	Georgia		485	2213				100	[illegible]	[illegible]		19		[illegible]
9	Hawaii													
10	Idaho													
5	Illinois				9509			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
5	Indiana							[illegible]		[illegible]		[illegible]		[illegible]
7	Iowa											[illegible]		[illegible]
7	Kansas				1295					179		[illegible]		[illegible]
4	Kentucky				1	10	2			[illegible]				[illegible]
6	Louisiana		295	325	69820				[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
1	Maine													
3	Maryland				565	11		[illegible]				[illegible]		[illegible]
1	Massachusetts				[illegible]	[illegible]	[illegible]							[illegible]
5	Michigan				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		
5	Minnesota							[illegible]						
4	Mississippi				[illegible]				[illegible]			[illegible]		[illegible]
7	Missouri				[illegible]							[illegible]		[illegible]
8	Montana													
7	Nebraska													
9	Nevada													
1	New Hampshire													
2	New Jersey				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6	New Mexico													
2	New York				[illegible]	[illegible]	44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
4	North Carolina				[illegible]	[illegible]	[illegible]							[illegible]
8	North Dakota													
5	Ohio				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6	Oklahoma													
10	Oregon							[illegible]				[illegible]		[illegible]
3	Pennsylvania				[illegible]	[illegible]	3	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
2	Puerto Rico				[illegible]					[illegible]			[illegible]	[illegible]
1	Rhode Island					[illegible]	[illegible]		[illegible]					[illegible]
4	South Carolina				[illegible]	[illegible]						[illegible]		[illegible]
8	South Dakota													
4	Tennessee				[illegible]	6		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
6	Texas				142754			[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
8	Utah				[illegible]									[illegible]
1	Vermont													
3	Virginia				[illegible]	[illegible]								[illegible]
10	Washington				[illegible]							[illegible]		[illegible]
3	West Virginia				[illegible]	34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
5	Wisconsin											[illegible]		[illegible]
8	Wyoming													
NATIONAL TOTALS		5491	6994	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REGION TOTALS	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
1				[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]		[illegible]
2				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
4	5491	6699	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]
5				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6		295	325	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
7				[illegible]					[illegible]		[illegible]		[illegible]
8				[illegible]							[illegible]		[illegible]
9				[illegible]	[illegible]	[illegible]	46	[illegible]	[illegible]		[illegible]		[illegible]
10				[illegible]			[illegible]				[illegible]		[illegible]

*Estimated, water-free basis, for components classified as [illegible] given in Section 3 and Appendix A. The data for the calculations were obtained from the [illegible] and References 3, 4, 8, 11, 12, 19-54.

Table 5-8. Hazardous Component Content*, Process Waste Stream Discharge to Land Disposal, Metric Tons for CY 1977 by Standard Industrial Classification — Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama	3539		350	27431	44		370	133	1867		21327		54,466
10	Alaska													
9	Arizona									77				[illegible]
6	Arkansas									1454		[illegible]		[illegible]
9	California				6445	8	7	57	190	42864	16	[illegible]		51,776
8	Colorado				32							[illegible]		[illegible]
1	Connecticut				235									[illegible]
3	Delaware				25276						[illegible]	[illegible]		[illegible]
3	District of Columbia									5988				[illegible]
4	Florida	2503	6836	779					[illegible]	28257		[illegible]		[illegible]
4	Georgia		533	2434				110	[illegible]	4741		[illegible]		[illegible]
9	Hawaii													
10	Idaho													
5	Illinois				19378			104	161	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Indiana				345			[illegible]		[illegible]	[illegible]	41		[illegible]
7	Iowa									[illegible]		[illegible]		[illegible]
7	Kansas				2864					534		[illegible]		[illegible]
4	Kentucky				867	11	[illegible]			[illegible]				[illegible]
6	Louisiana		[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	549	[illegible]		[illegible]
1	Maine													
3	Maryland				[illegible]	11		416				[illegible]		[illegible]
1	Massachusetts				[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]
5	Michigan				[illegible]	[illegible]	[illegible]	[illegible]	14	4404	[illegible]	[illegible]		[illegible]
5	Minnesota							[illegible]			[illegible]			[illegible]
4	Mississippi				[illegible]									[illegible]
7	Missouri				[illegible]				[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
8	Montana									[illegible]	[illegible]	[illegible]		[illegible]
7	Nebraska									447				[illegible]
9	Nevada				[illegible]									
1	New Hampshire													[illegible]
2	New Jersey				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	New Mexico													
2	New York				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
4	North Carolina				[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		
8	North Dakota													[illegible]
5	Ohio				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6	Oklahoma									[illegible]				[illegible]
10	Oregon							[illegible]						
3	Pennsylvania				[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	Puerto Rico				[illegible]					[illegible]			[illegible]	[illegible]
1	Rhode Island					[illegible]	[illegible]				[illegible]			[illegible]
4	South Carolina				[illegible]	[illegible]				[illegible]				[illegible]
8	South Dakota													
4	Tennessee				[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6	Texas				[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
8	Utah				[illegible]			[illegible]						[illegible]
1	Vermont													
3	Virginia				[illegible]									[illegible]
10	Washington				[illegible]					[illegible]		[illegible]	[illegible]	[illegible]
3	West Virginia				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
5	Wisconsin				[illegible]							[illegible]		[illegible]
8	Wyoming									[illegible]		[illegible]		[illegible]
NATIONAL TOTAL		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REGION TOTALS													
1				[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
2				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
6		[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7				[illegible]					[illegible]	[illegible]	[illegible]		[illegible]
8				[illegible]			[illegible]		[illegible]		[illegible]		[illegible]
9				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
10				[illegible]			[illegible]		[illegible]		[illegible]	[illegible]	[illegible]

*Estimated water-free basis, for components classified as "Moderately Dangerous" or "Highly Dangerous" in this study, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table [illegible] and References [illegible].

Table 5-9. Hazardous Component Content* Process Waste Stream Discharge to Land Disposal, Metric Tons for CY 1983 by Standard Classification – Organic Chemicals and Technical Pesticides Industries

EPA Region	State	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL
4	Alabama	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	Alaska	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	Arizona	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	Arkansas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	California	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	Colorado	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Connecticut	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	Delaware	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	District of Columbia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Florida	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Georgia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	Hawaii	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	Idaho	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Illinois	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Indiana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Iowa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Kansas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Kentucky	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	Louisiana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Maine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	Maryland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Massachusetts	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Michigan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Minnesota	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Mississippi	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Missouri	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	Montana	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	Nebraska	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	Nevada	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	New Hampshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	New Jersey	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	New Mexico	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	New York	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	North Carolina	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	North Dakota	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Ohio	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	Oklahoma	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	Oregon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	Pennsylvania	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	Puerto Rico	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Rhode Island	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	South Carolina	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	South Dakota	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	Tennessee	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	Texas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	Utah	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	Vermont	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	Virginia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	Washington	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	West Virginia	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	Wisconsin	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	Wyoming	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NATIONAL TOTALS		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REGION TOTALS														
1		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Estimated, water-free basis, for components classified as "Moderately Dangerous" or "Highly Dangerous" in this study, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry survey [illegible] References 3, 4, 8, 11, 12, 19-34.

The situation changes very sharply based on projections of the effects of the Federal Water Pollution Control Act as amended. The quantity of hazardous components discharged to land by the SIC 28692 product group in 1977 was estimated to be 1.25 million metric tons, an increase of 850,000 metric tons. The increase in hazardous component discharge to land for 1977 by SIC 28651 is less than 200,000 metric tons, bringing the total to 0.6 million metric tons. In 1977, SIC 28692 and SIC 28651 hazardous component discharges to land constitute 92 percent of the 2.0 million tons of such components discharged by the industry. The hazardous component content discharge factors projected are 0.022 kg per kg of product for the industry, 0.018 kg per kg product for product group SIC 28692, and 0.036 kg per kg product for product group SIC 28651.

The projections of hazardous component quantities discharged to land for 1983 are of the same relative order and magnitude as those for 1977; product group SIC 28692, 1.4 million metric tons, hazardous components discharge factor 0.018 kg per kg product; product group SIC 28651, 0.7 million metric tons, hazardous components discharge factor 0.036; and overall organic chemical industry, 2.2 million metric tons, hazardous components discharge factor 0.022 kg per kg product.

Table 5-10 lists the highly dangerous components in the process waste streams discharged to the land by the organic chemicals industry. Tables 5-11, 5-12, and 5-13 present estimates of the total quantities of these highly dangerous components discharged to land disposal for the years 1973, 1977 and 1983, tabulated for each state and region by the individual product groups of the organic chemicals industry.

The manufacturers of the miscellaneous acyclic chemicals and chemical products of SIC 28692 discharge the greatest quantities of highly dangerous components to land disposal in each of the 3 years for which estimates were made. In each year, the discharges of the three highest product groups (SIC 28692, SIC 28651, and SIC 28694) amount to 98 percent or more of the total industry discharge to land of highly dangerous components. In each of the 3 years, Texas and Louisiana are the states highest in quantity of highly dangerous waste components to land disposal.

The quantities and highly dangerous waste component discharge factors for 1973 for the two most pollution prone product groups and for the

Table 5-10. Highly Dangerous Waste Stream Components by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries

SIC	Highly Dangerous Component
28651	Aluminum oxide (DPA contaminated catalyst)
	Amines
	Ammonia
	Azobenzene
	Benzidine
	Benzidine hydrochloride
	Chlorinated aromatics
	Chlorotoluene and phenol
	Cyclopentadiene
	Dichloroanilines
	Dichloroethane
	Dicyclopentadiene
	Dinitrotoluenes
	Diphenylamine
	Heavy metal catalyst from melamine manufacture
	Heavy organics from p-nitroaniline manufacture
	Hydrazobenzene
	Hydroquinone
	Isocyanates
	Manganese oxides
	Melamine
	Methyl aniline
	α-naphthylamine
	β-naphthylamine
	Nitrobenzene
	Nitrobenzene sulfonic acid
	Nitrotoluene
	N-phenylhydroxylamine
	N,N-diethylaniline
	Phenol
	Phenolics
	Phenylenediamines
	Phosgene
	Phthalic anhydride
	Polymeric matter, phenol contaminated
	Polymers and tarry matter from isocyanates manufacture
	p-chlorophenol
	p-hydroxybenzoic acid
	p-nitroaniline
	p-nitrochlorobenzene
	p-nitrotoluene sulfonic acid
	Quinone
	Resorcinol, phenol and cresol
	Resorcinol
	Sodium phenoxide
	Spent catalyst and support
	Sulfuric acid
	Tars from diphenylamine manufacture

Table 5-10. Highly Dangerous Waste Stream Components by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries (Continued)

SIC	Highly Dangerous Component
28651	Tars and naphthylamine from α and β naphthylamine manufacture
	Toluene diamine
	Toluidine
	2-naphthylamine
	2,4 dimethylaminoazo benzene
	3,3'-dichlorobenzidine
28652	Aminotoluene
	Chloroacetic acid
	Dinitrophenol
	Phenol
	p-anisidine
	p-formamidoanisole
	p-hydroxyaniline
	o-anisidine
	o-formamidoanisole
	o-hydroxyaniline
	o-nitrophenol
	2-aminotoluene
	2-amino, 4-nitrophenol
	2-nitro, 4-aminophenol
	2-nitro, 4-amino anisole
	2,4-diaminotoluene
	4-aminotoluene (paren-toluidine)
28653	Naphthylamine
	N-ethylnaphthylamine
	p-toluidine
	p-toluidine-2-sulfonic acid
	p-toluidine-3-sulfonic acid
	3,3'-dichlorobenzidine
28655	Phenols
28691	Acetylamino fluorene
	Ferric chloride
	Napthenic acid
	Napthenic acid salts
	Phenol
	Phenolic salts
	p-cresol
	Thionyl chloride
	Zinc dust
	2,6 di-tert-butyl-p-cresol
28692	Acetonitrile
	Acrolein
	Acrylic acid

Table 5-10. Highly Dangerous Waste Stream Components by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries (Continued)

SIC	Highly Dangerous Component
28692	Acrylonitrile
	Allyl alcohol
	Allyl chloride
	Ammonia
	Ammonium cyanide
	Ammonium methacrylate
	Antimony oxide
	Antimony pentachloride
	β-propiolactone
	Carbon tetrachloride
	Chlorinated aldehydes
	Chlorine
	Chloroacetic acid
	Chloroamino ethanes
	Copper (recov) from acetaldehyde manufacture
	Crotonaldehyde
	Crude hexachlorobenzene
	Dichloroethane
	Dichloroethylene
	Diethylamine
	Dimethyl ethers
	Epichlorohydrin
	Ethyleneamines
	Ethylene diamine
	Ethylene dichloride
	Ethylene oxide
	Ethyleneimine
	Ethyl acrylate
	Fluorocarbons
	Heavy ends from acetic anhydride manufacture
	Heavy metal catalyst from n-paraffins manufacture
	Heavy tars from vinyl chloride manufacture
	Hexamethyleneimine
	Hydrogen chloride
	Hydrogen cyanide
	Hydroquinone
	Lead sludge
	Mercuric tin hydroxide
	Metallic fluorinating agent
	Methylchloromethylether
	Methyl ethyl ketone
	Methyl methacrylate
	Mixed heavy chlorinated hydrocarbons
	Na salt of EDTA
	Nickel from hexylene glycol manufacture
	Nickel chloride
	N-chlorodimethyl amine
	N-nitrosodimethyl amine

Table 5-10. Highly Dangerous Waste Stream Components by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries (Continued)

SIC	Highly Dangerous Component
28692	Phenols
	Pentachloroethane
	Perchloroethylene
	Phenol/aniline
	Polymers from acrylic acid/acrylates manufacture
	Polymers and hydroquinone from methyl methacrylate manufacture
	Propionic acid
	Propylene oxide
	Propyl aldehyde
	Sodium acrylate
	Sodium cyanide
	Sodium fluoride
	Sodium formate
	Stearic acid
	Stearic acid salts
	Tars from ethylene diamine manufacture
	Tetrachloroethane
	Tetrachloroethylene
	Trichloroethane
	Trichloroethylene
	Trichloropropane
	Vinyl chloride
	Vinyl chloride contam. solids
	Vinylidene chloride
	Zinc acetate/on coke
	1,1,2-trichloroethane
28693	Alkylated phenol
	Benzyl chloride
	Dodecylmercaptans
	Myristic acid
	Myristic acid ester
	Organic mercaptan salts
	Partial phosphate esters
	Phenols
	Spent activated carbon from phosphoric acid ester manufacture
	Stearic acid and esters
	Tars from benzothiazole manufacture
	Unreacted phenol
28694	Acrolein
	Aldicarb
	Aldrin
	Alpha-naphthylthiourea
	Arsenic trioxide
	Atrazine
	Bis(chloromethyl ether)
	Chlorinated methyl ethers

Table 5-10. Highly Dangerous Waste Stream Components by Standard Industrial Classification, Organic Chemicals and Technical Pesticides Industries (Continued)

SIC	Highly Dangerous Component
28694	Captan
	Carbofuran
	Carbaryl
	Carbophenothion
	Chlordane
	2,4-Dichlorophenol
	2,6-Dichlorophenol
	2,2-Dichlorovinyl dimethyl phosphate
	Dieldrin
	O,O-Diethyl O-(3-chloro-4 methyl-2-oxo-2H-1-benzopyran-7-yl) phosphorothioate
	O,O-Diethyl S-[2-ethylthio)ethyl] phosphorodithioate
	O,O-Diethyl O-2-pyrazinyl phosphorothioate
	Dimethoate
	O,O-Dimethyl O-p-nitrophenyl phosphorothioate
	O,O-Dimethyl S-[(4-oxo-1,2,3-benzotriazin-3(4H)-yl methyl] phosphorodithioate
	Dimethyl phosphate ester with 3-Hydroxy-N,N-Dimethyl-cis-crotonamide
	Dimethyl phosphate of 3-Hydroxy-N-methyl-cis-crotonamide
	Dinoseb
	Dioxathion
	Diphacinone
	Diuron
	Endothall
	Endrin
	Ethyl hexanediol
	Ethyl thiocarbonate
	Ethion
	O-Ethyl S-phenyl ethylphosphorodithioate
	S-[2-(Ethylsulfinyl)ethyl]O-O-Dimethyl phosphorothioate
	Heavy carbamate residues
	Hydrazine
	Hydrogen sulfide
	Heptachlor
	Malathion
	Methomyl
	Methyl chloroacetate
	Methyl fluoroacetate
	Methyl isocyanate
	1-Naphthylamine hydrochloride
	Nicotine
	Phenol
	Phenolic resins from 2,4-dichlorophenoxyacetic acid manufacture
	Parathion
	Polymers and tars, pesticide contaminated from warfarin manufacture
	Phosphamidon

Table 5-10. Highly Dangerous Waste Stream Components by Standard Industrial Classification. Organic Chemicals and Technical Pesticides Industries (Continued)

SIC	Highly Dangerous Component
28694	Sodium p-nitrophenolate
	Tarry residues, pesticide contaminated from malathion manufacture
	Sodium fluoroacetate
	Tetraethyl pyrophosphate
	2,4,6-trichlorophenol
	Toxaphene
	Warfarin

Table 5-11. Highly Dangerous Component Content*, Process Waste Stream Discharge to Land Disposal, Metric Tons for CY 1973 by Standard Industrial Classification – Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama				2800			324	191	544		9837		13,696
10	Alaska													
9	Arizona													
6	Arkansas											582		582
9	California				1308	.1	2	46	2	2822		2780		6,960
8	Colorado											52		52
1	Connecticut										62	11		73
3	Delaware				478									478
3	District of Columbia													
4	Florida									2010				2,010
4	Georgia							100				9		109
9	Hawaii													
10	Idaho													
5	Illinois				2808			167	2	279	13	836		4,105
5	Indiana							183				32		215
7	Iowa											417		417
7	Kansas				966					179		254		1,399
4	Kentucky				1	1	1			8441				8,444
6	Louisiana				10336				117	29851		6131		46,234
1	Maine													
3	Maryland					3		417				4		424
1	Massachusetts				0.1	22	3							25
5	Michigan				1951	1	5	139		170	2	1352		3,616
5	Minnesota							46				14		60
4	Mississippi				762							2391		3,153
7	Missouri				20						1	521		542
8	Montana													
7	Nebraska													
9	Nevada													
1	New Hampshire													
2	New Jersey				8003	256	69	46	27	681	1	2357		11,440
6	New Mexico													
2	New York				6	100	14			1542	715	197		2,574
4	North Carolina				595	85	11							691
8	North Dakota													
5	Ohio				355	16	6	406	14	4734	88	46		5,565
6	Oklahoma													
10	Oregon							46				254		300
3	Pennsylvania				10247	38	2	139		3281	33	72		13,763
2	Puerto Rico				4137					4092				8,229
1	Rhode Island					6	1							7
4	South Carolina				479	23						53		555
8	South Dakota													
4	Tennessee				637			72	375	6555		2096		9,740
6	Texas				14526			341		59970	705	4468		80,162
8	Utah							77						77
1	Vermont													
3	Virginia											1		1
10	Washington				2222							499		[illegible]
3	West Virginia				3618	1	15	46		7981	15			[illegible]
5	Wisconsin											79		79
8	Wyoming													
NATIONAL TOTALS					[illegible]	536	126	[illegible]	729	133,282	1,630	35,315		240,105

REGION TOTALS		28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
1					1	28	4				62	11		106
2					12146	356	83	46	27	6315	716	2554		22,243
3					14343	41	18	607		11262	43	28		26,335
4					5274	109	12	561	566	17550		14386		38,398
5					5114	16	6.5	441	16	6182	133	2380		[illegible]
6					24681			541	117	89771	705	11181		126,976
7					966					179	1	1192		2,338
8								77				52		129
9					1308	.1	2	46	2	2822		2780		6,960
10					2222			46				753		3,021

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*Estimated, water-free basis, for components classified as "Highly Dangerous" in this study, using the procedures given in Section 3 and Appendix I. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3, 4, 8, 11, 12, 14-54.

Table 5-12. Highly Dangerous Component Content[*] Process Waste Stream Discharge to Land Disposal, Metric Tons for CY 1977 by Standard Industrial Classification – Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama				3134			357	11	607		14760		18,869
10	Alaska													
9	Arizona									1454		640		2,094
6	Arkansas				1999	0.02	2	51	3	18871		1153		22,079
9	California											58		58
8	Colorado										77	24		101
1	Connecticut				525					1156				1,681
3	Delaware													
3	District of Columbia									415		20		435
4	Florida							110		117		10		237
4	Georgia													
9	Hawaii													
10	Idaho				4208			184	3	7626	71	870		12,962
5	Illinois				255			201		1056		35		1,547
5	Indiana									1799		434		2,233
7	Iowa				1083					626		279		1,988
7	Kansas				659	2	1			24866				25,528
4	Kentucky				12599				129	[illegible]	7	[illegible]		144,341
6	Louisiana													
1	Maine				3	3		459		1		84		552
3	Maryland				0.2	24	3							27
1	Massachusetts				2186	0.1	0.6	153		870	28	1151		4,389
5	Michigan							51				30		81
5	Minnesota				1039							5904		6,943
4	Mississippi				27					97	11	[illegible]		[illegible]
7	Missouri													
8	Montana													
7	Nebraska													
9	Nevada								11					11
1	New Hampshire				12656	273	73	52	60	6099	46	5551		24,810
2	New Jersey													
6	New Mexico				13	106	15		13	1556	593	[illegible]		[illegible]
2	New York				637	90	12		44		5	0.7		789
4	North Carolina													
8	North Dakota				533	17	7	337	150	2265	114	[illegible]		[illegible]
5	Ohio									164				164
6	Oklahoma							51				179		230
10	Oregon				12953	41	3	163		5360	51	[illegible]		[illegible]
3	Pennsylvania				5477					49459				[illegible]
2	Puerto Rico					6	1							
1	Rhode Island				532	24						119		675
4	South Carolina													
8	South Dakota				712			85	[illegible]	8617		[illegible]		[illegible]
4	Tennessee				18647			595		211457	115	3872		[illegible]
6	Texas							84						84
8	Utah													
1	Vermont									235		[illegible]		[illegible]
3	Virginia				2498							848		3,067
10	Washington				6226	0.1	16	68	10	14149	42			20,503
3	West Virginia				69							48		106
5	Wisconsin													
8	Wyoming													
NATIONAL TOTALS					88,865	598	138	3,748	1,287	505,360	1,992	58,557		659,744

REGION TOTALS	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
1					30	4		11		77	.4		136
2				18146	379	88	52	82	57114	639	5788		82,400
3				19707	44	19	690	10	20703	93	106		41,372
4				6732	116	13	[illegible]	867	34656	6	25447		68,401
5				7251	17	8	920	161	16757	166	2897		28,161
6				31846			595	129	357243	782	12756		407,851
7				1105					2022	17	2409		5,553
8							84				58		142
9				1999		2	51	3	18871		1153		22,079
10				2498			51				848		3,397

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[*] Estimated, water-free basis, for components classified as "Highly Dangerous" in this study, using the procedures given in Section 3 and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3, 4, 8, 11, 12, 19-54.

Table 5-13. Highly Dangerous Component Content* Process Waste Stream Discharge to Land Disposal Metric Tons for CY 1983 by Standard Industrial Classification — Organic Chemicals and Technical Pesticides Industries

EPA Region	State	28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
4	Alabama				3464			394	12	671		16316		20,857
10	Alaska													
9	Arizona													
6	Arkansas											707		707
9	California				2210	1	2	56	3	18650		3486		24,407
8	Colorado											64		64
1	Connecticut										85	27		112
3	Delaware				581					1278				1,859
3	District of Columbia													
4	Florida									456		22		478
4	Georgia							121		129		11		261
9	Hawaii													
10	Idaho													
5	Illinois				4652			203	3	8430	24	1017		14,329
5	Indiana				282			222		1167		39		1,710
7	Iowa									1436		480		1,916
7	Kansas				1197					692		309		2,198
4	Kentucky				729	2	1			27490				28,222
6	Louisiana				13927				142	137262	8	8444		159,783
1	Maine													
3	Maryland				4	3		507		3		93		610
1	Massachusetts				1	25	3							29
5	Michigan				2416	1	6	169		895	31	1930		5,450
5	Minnesota							56				33		89
4	Mississippi				1149							5863		7,012
7	Missouri				24					708	19	3464		4,215
8	Montana													
7	Nebraska													
9	Nevada													
1	New Hampshire								12					12
2	New Jersey				13990	291	78	18	63	6142	51	4135		[illegible]
6	New Mexico													
2	New York				14	113	16		25	1720	876	262		3,026
4	North Carolina				726	97	13		48		[illegible]	[illegible]		891
8	North Dakota													
5	Ohio				567	19	6	[illegible]	74	6041	131	71		[illegible]
6	Oklahoma									181				181
10	Oregon							56				309		365
3	Pennsylvania				14319	43	4	[illegible]		5711	57	25		[illegible]
2	Puerto Rico				6055					58671				64,726
1	Rhode Island					6	1							7
4	South Carolina				[illegible]	26						131		[illegible]
8	South Dakota													
4	Tennessee				787			93	319	9563		5277		[illegible]
6	Texas				[illegible]			[illegible]		[illegible]	467	10417		[illegible]
8	Utah							[illegible]						[illegible]
1	Vermont													
3	Virginia									360		3		363
10	Washington				[illegible]							[illegible]		[illegible]
3	West Virginia				[illegible]	[illegible]	17	[illegible]	[illegible]	[illegible]	46			22,664
5	Wisconsin				[illegible]							46		[illegible]
8	Wyoming													
NATIONAL TOTALS					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

REGION TOTALS		28610	28611	28612	28651	28652	28653	28655	28691	28692	28693	28694	28695	TOTAL
1					[illegible]	[illegible]	[illegible]		12		85	27		[illegible]
2					[illegible]	[illegible]	94	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
3					[illegible]	46	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]
4					[illegible]	[illegible]	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		75,055
5					[illegible]	[illegible]	9	[illegible]	[illegible]	[illegible]	[illegible]	3,198		[illegible]
6					[illegible]			[illegible]	142	[illegible]	[illegible]	[illegible]		449,362
7					[illegible]					3,236	19	2,753		[illegible]
8								[illegible]				64		[illegible]
9					[illegible]	[illegible]	[illegible]	56	[illegible]	[illegible]		[illegible]		[illegible]
10					[illegible]			56				[illegible]		[illegible]

*Estimated, water-free basis, for components classified as "highly dangerous" in this study, using the procedures given in Section [illegible] and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table [illegible] and References [illegible], 4, [illegible], [illegible], [illegible], 19-54.

industry are as follows: SIC 28692, 133,000 metric tons, 0.0021 kg per kg product; SIC 28651, 66,000 metric tons, 0.0042 kg per kg product; organic chemicals industry, 249,000 metric tons, 0.0028 kg per kg product. The statistics for 1977 and 1983 are based on the assumptions stated earlier on the increase in discharge to land predicated as the result of the requirements of the FWPCA as amended; the estimated waste discharges differ considerably from those presented for 1973.

The increase in the quantity of highly dangerous components discharged to land disposal is greatest in 1977 for SIC 28692, in both absolute tonnage and relative rise. The tonnage of highly dangerous waste stream constituents for SIC 28692 in 1977 is projected as 0.5 million metric tons, an increase of 280 percent over the 1973 estimate. Similar figures for SIC 28651 are an increase to 89,000 metric tons, which is only 35 percent higher than the 1973 estimate for the product group. The highly dangerous component waste discharge factors projected for 1977 are: SIC 28692, 0.0074 kg per kg product; SIC 28651, 0.0052 kg per kg product; organic chemicals industry, 0.0071 kg per kg product.

The projections for 1983 of highly dangerous component quantities discharged as waste to land reflect only the increases above 1977 due to increases in production. The order and magnitudes of the highly dangerous component waste discharges for the product groups are, therefore, the same for 1983 as for 1977; the component waste discharge factors are identical. The overall projection for the organic chemicals industry in 1983 is a highly dangerous components discharge to waste of 0.7 million metric tons; three-fourths of this results from the manufacture of the products of SIC 28692.

5.3 PESTICIDES INDUSTRIES

The pesticides industries are treated throughout this study as two entities: technical pesticides manufacture (SIC 28694), and pesticides preparations and formulations production (SIC 2879).

Emphasis has been placed in the characterization of wastes from the pesticides industries on the discharges and technologies of the technical pesticides manufacturing industry (SIC 28694). The reasons, as noted in Section 3 and in Appendix A, are twofold: First, and most important, are the much higher quantities of hazardous wastes anticipated from technical pesticides plants, as opposed to the relatively low quantities estimated for pesticides formulations and preparations production. Second is that this study's lack of access to quantitative data other than gross national statistics on pesticides formulations and preparations production caused problems. Detailed information on the annual production of each formulation at each plant site was treated as proprietary by the companies involved and was not available from trade publications.

Because of the very sensitive nature of the pesticide manufacturing and formulation industries, very little information is available on specific details of production and formulation operations for a large number of individual pesticides and pesticide preparations. Most manufacturers and formulators are extremely reluctant to reveal technical process data. Several pesticide manufacturers and formulators were contacted for data. One major manufacturer, who in recent years had received some adverse publicity on its waste disposal practices, flatly refused to discuss their operation or to provide pertinent data for use in this study. Some of the other manufacturers who allowed production-site interviews did not permit their personnel to elaborate beyond what is common technical knowledge and had been published in the literature. The list of pesticide company headquarters and plants which were visited, shown in Table A-1, has been expanded to show the products for which data were obtained and is presented as Table 5-14.

As a result of the lack of published data and a lack of full cooperation from the majority of the manufacturers contacted, specific data on the manufacturing processes, mass balances, and nature and quantities of raw materials used and wastes generated were not available for many of the technical pesticides considered. Accordingly, the simplified approach, noted in Section 3 for grouping the technical pesticides into "chemical" classes and selecting one to three pesticides from each class as group representatives for more in-depth analysis, was used for process technology review, and for estimation of waste quantities. This approach was deemed adequate since many of the pesticides in each group share similar process chemistries and are produced from the same starting raw materials. For example, as indicated in Figure 5-22, cyanuric chloride is the starting material for the

Table 5-14. Companies Providing Information on Pesticide Manufacturing/Formulation and Waste Disposal Methods

Company Headquarters or Plant Sites	Pesticide Produced or Formulated
Union Carbide Corp. Institute, West Virginia	Carbaryl
Standard Oil Co. of Calif. (Chevron Chemical Co.) San Francisco, Calif.	Formulated products containing chlordane, dibrom, diquat, endrin, aldrin, acephate, buxten, difolatan, captol, arsenates, sevin, dieldrin, hethyl parathion, parathion, monitor, paraquat, phosphamidon, toxaphene, lindane, 2,4,5-T, DDT, 2,4-D, arsenic compounds and pentachlorophenol
Reichhold Chemicals, Inc. Tacoma, Washington	Pentachlorophenol
Shell Oil Co. (Shell Chemical Co.) Axis, Alabama	Dichlorvos, nemagon, phosdrin, gardona, aldicarb
Monsanto Co. (Monsanto Commercial Products Co.), St. Louis, Mo; Anniston, Al; Muscatine, La.	Niran, propachlor, alachlor, triallate, diallate
Stauffer Chemical Co. (Agricultural Chemical Division) Westport, Ct; Omaha, Nb; Mt. Pleasant, Tn.	Methyl parathion, ethyl parathion (discontinued in 1973), organic phosphate, granular formulations (diphenate, diazinone); thiocarbate granular formulations, seed protectant, wettable and dry powders
Dow Chemical Company Midland, Mi; Freeport, Tx.	2,4-D, dibromochloropropane, ethylene dibromide, DNBP, trichlorophenol
Rhodia Inc. (Chipman Division) Portland, Or; St. Joseph, Mo.	2,4-D, MCPA, MCPB, 2,4-DB, bromoxynil octanoate, 2,4-DP, MCPP
Eli Lilly and Company (ELANCO) Lafayette, Indiana	Trifluralin

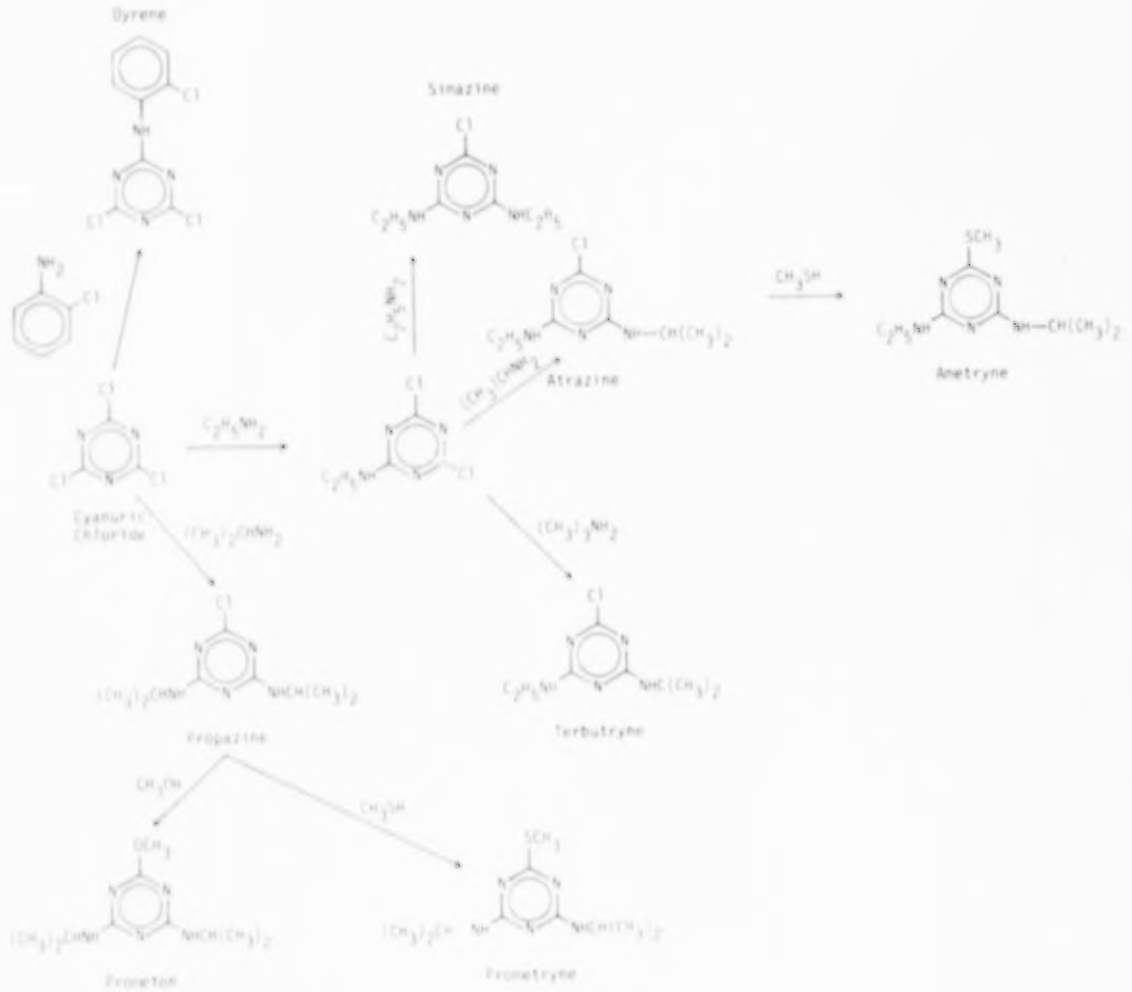
Dyrene
Simazine
Atrazine
Ametryne
Cyanuric Chloride
Propazine
Terbutryne
Prometon
Prometryne
C2H5NH2
(CH3)2CHNH2
(CH3)3NH2
CH3SH
CH3OH

Figure 5-22. Synthesis of Triazine Pesticides

synthesis of triazine pesticides and the synthesis involves reaction of cyanuric chloride with alkyl or aryl amines.

The 127 technical pesticides considered in this study (i.e., as indicated in Appendix A, those with national production quantities close to or in excess of 453 metric tons/year, and those produced at somewhat smaller quantities but considered extremely hazardous) are listed in Table 5-15, grouped into 17 classes. Based on this chemical classification system, these pesticides consist of 19 chlorinated aromatics, eight chlorinated polycyclics, five halogenated aliphatics, five ureas, one thiourea, six phosphate and pyrophosphates, 11 phosphorothioates, 14 phosphorodithioates, eight carbamates, ten amides and imides, two arsenicals, 15 biological and natural products, three triazines, two uracils, six nitro compounds, six thiocarbamates, and 12 miscellaneous products. The pesticides selected as class representatives (a total of 32) are marked by an asterisk in Table 5-15. Selection of class representatives was based on the extent of data available, production volume, number and distribution of manufacturing sites, and hazard characteristics of the waste streams, products, raw materials and intermediates.

5.3.1 Typical Plant Process and Waste Stream Descriptions

Five of the 32 class representatives for the technical pesticides group have been selected for presentation of process flow diagrams, mass balances, and waste stream descriptions. Combined total production in 1972 for the five technical pesticides selected was estimated to constitute approximately 26 percent of the national total for production of all technical organic pest control chemicals. Combined total process wastes discharged to land (dry weight basis) for the five technical pesticides are estimated to constitute 19 percent of the national total dry weight of process wastes discharged to land by all technical organic pesticides plants. The five technical pesticides selected were, therefore, adequately representative of product group SIC 28694. A brief description of the production operations of a hypothetical plant for each of these five pesticides follows. Again, it should be noted that the descriptions presented are composites, rather than any single plant.

Table 5-15. Pesticides Considered in SIC 28694 and Their Grouping into Chemical Classes[1] (Pesticides Marked by Asterisks are Class Representatives)

Group 1 – Chlorinated Aromatics

- Barban
- 1,1-Bis(chlorophenyl)-2,2,2-trichloroethanol
- Chloramben
- Dicamba
- *Dichloro diphenyl trichloroethane
- 2,6-Dichloro-4-nitroaniline
- *2,4-Dichlorophenoxyacetic acid
- Dimethyl tetrachloroterephthalate
- Ethyl 4,4'-dichlorobenzilate
- Isopropyl 4,4'-dichlorobenzilate
- Lindane (gamma isomer of benzene hexachloride)
- Linuron
- Methoxychlor
- Pentachloronitrobenzene
- Pentachlorophenol
- Silvex
- 2,3,6-Trichlorobenzoic acid and related polychlorobenzoic acids, dimethylamine salts
- *2,4,5-Trichlorophenoxyacetic acid

Group 2 – Chlorinated Polycyclics

- *Aldrin
- *Chlordane
- *Dieldrin
- Dodecachlorooctahydro-1,3,4-metheno-1H-cyclobuta[cd]pentalene
- Endosulfan
- Endrin
- Heptachlor
- *Toxaphene

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[1] The nomenclature employed is taken from Reference 13.

Table 5-15. Pesticides Considered in SIC 28694 and Their Grouping into Chemical Classes[1] (Pesticides Marked by Asterisks are Class Representatives) (Continued)

Group 3 — Halogenated Aliphatics

*Dalapon
1,2-Dibromo-3-chloropropane
*Methyl bromide
Sodium fluoroacetate
Trichloroacetic acid

Group 4 — Ureas

Chloroxuron
*Diuron
Maloran
*Norea
Siduron

Group 5 — Thioureas

*Alpha-naphthylthiourea

Group 6 — Phosphate and Pyrophosphates

Crufomate 4-tert-butyl-2-chlorophenyl methyl methylphosphoramidate
2,2-Dichlorovinyl dimethyl phosphate
*Dimethyl phosphate ester with 3-Hydroxy-N,N-dimethyl-cis-crotonamide
*Dimethyl phosphate of 3-Hydroxy-N-methyl-cis-crotonamide
Phosphamidon
Tetraethyl pyrophosphate

Group 7 — Phosphorothioates

Chloropyrifos
O-(2,4-Dichlorophenyl)O,O-diethyl phosphorothioate
O,O-Diethyl O-(3-chloro-4 Methyl-2-oxo-2H-1-benzopyran-7-yl) phosphorothioate
O,O-Diethyl O-(2-isopropyl-6-methyl-4-pyrimidinyl)phosphorothioate
*O,O-Dimethyl O-p-nitrophenyl phosphorothioate
S-[2-(Ethylthio)ethyl] O,O-dimethyl phosphorodithioate

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[1] The nomenclature employed is taken from Reference 13.

Table 5-15. Pesticides Considered in SIC 28694 and Their Grouping into Chemical Classes[1] (Pesticides Marked by Asterisks are Class Representatives) (Continued)

*Parathion

Ronnel

0,0,0,0'-Tetramethyl 0,0'-thiodi-p-phenylene phosphorothioate

0,0,0,0-Tetrapropyl dithiopyrophosphate

Group 8 — Phosphorodithioates

Carbophenothion

0,0-Diethyl 0-[-p(methylsulfinyl)phenyl]phosphorothioate

*0,0-Diethyl S-[2-(ethylthio)ethyl]phosphorodithioate

Dimethoate

0,0-Dimethyl S-[(4-oxo-1,2,3-benzothiazin-3(4H)-yl)methyl] phosphorodithioate

3-(0,0-Diisopropyl phosphorodithioate)ester of N-(2-mercaptoethyl) benzenesulfonamide

Dioxathion

Ethion

0-Ethyl S,S-dipropyl phosphorodithioate

0-Ethyl S-phenyl ethylphosphorodithioate

Haled

*Malathion

S,S,S-Tributyl phosphorotrithioate

Tributyl phosphorotrithioite

Group 9 — Carbamates

*Aldicarb

Benomyl

*Carbaryl

Carbofuran

2,6-Di-tert-butyl-p-tolyl methylcarbamate

0-Ethyl hexahydro-1H-azepine-1-carbothioate

M-(1-Ethylpropyl)phenyl methylcarbamate mixture with M-(1-methylbutyl) phenyl methylcarbamate

Methomyl

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[1] The nomenclature employed is taken from Reference 13.

Table 5-15. Pesticides Considered in SIC 28694 and Their Grouping into Chemical Classes[1] (Pesticides Marked by Asterisks are Class Representatives) (Continued)

Group 10 — Amides and Imides

- *Alachlor
- *Captan
- 2-Chloro-N-isopropylacetanilide
- N,N-Diallyl-2-chloroacetamide
- 3',4'-Dichloropropionanilide
- N,N-Diethyl-meta-toluamide
- Diphenamid
- N-1-Naphthylphthalamic acid
- N-Octyl bicycloheptenedicarboximide
- Cis-N-[(1,1,2,2-Tetrachloroethyl)thio]-4-cyclohexene-1,2-dicarboximide

Group 11 — Arsenicals

- *Cacodylic acid
- Disodium methanearsonate; Monosodium acid methanearsonate

Group 12 — Biological and Natural Products

- *Bacillus thuringiensis
- Nicotine
- Polyhedrus virus
- *Pyrethrins
- Rotenone

Group 13 — Triazines

- *Atrazine
- 2-Chloro-4,5-bis(isopropyl amino)-S-triazine
- Simazine

Group 14 — Uracils

- *Bromacil
- Terbacil

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[1] The nomenclature employed is taken from Reference 13.

Table 5-15. Pesticides Considered in SIC 28694 and Their Grouping into Chemical Classes[1] (Pesticides Marked by Asterisks are Class Representatives) (Continued)

Group 15 — Nitro Compounds

Binapacryl

N-Butyl-N-ethyl-alpha,alpha,alpha-trifluoro-2,6-dinitro-p-toluidine

2,4-Dinitro-6-octyl phenyl crotonate;2,6-dinitro-4-octyl phenyl crotonate

Dinoseb

4-(Methylsulfonyl)-2,6-dinitro-N,N-dipropyl-aniline

*Trifluralin

Group 16 — Thiocarbamates

2-chloroallyl diethyldithiocarbamate

S-(2,3-Dichloroallyl)diisopropylthiocarbamate

S-Ethyl cyclohexylethylthiocarbamate

*S-Ethyl diisobutylthiocarbamate

S-Propyl butylethylthiocarbamate

*S-Propyl dipropylthiocarbamate

Group 17 — Miscellaneous

Acrolein

Amitrole

*1,2-Dihydro-3,6-pyridazinedione

Diphacinone

Dipropyl isocinchomeronate

Dodine

Endothall

Ethyl hexanediol

Piperonal,bis[2-butoxyethoxy)ethyl]acetal

Piperonyl butoxide

2-(p-Tert-butylphenoxy)cyclohexyl 2-propynyl sulfite

*Warfarin

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[1] The nomenclature employed is taken from Reference 13.

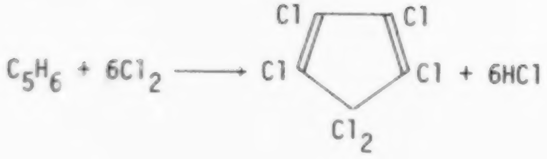
Aldrin(40, 47)

Aldrin is a chlorinated hydrocarbon used for control of a broad spectrum of insects. Pure aldrin is a white crystalline substance with a melting point of 104-104.5°C. In the soil, plants, insects and invertebrates aldrin is convered to dieldrin which is environmentally persistent. It is a highly toxic bioaccumulative substance with reputed toxicity data indicating a 96-hour TL_m of less than 0.1 ppm and an oral LD_{50} (male rat) of 39 mg/kg.(53) The production of aldrin has been discontinued, and the pesticide has been deregistered. In 1972, production of aldrin was estimated as 4,500 metric tons (19 million pounds); the sole producer reported was Shell Chemical.(42)

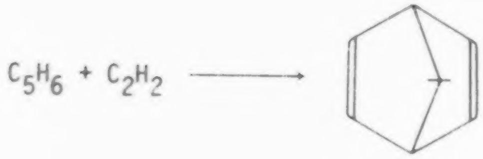
Technical grade aldrin is a brown substance with a melting point in the 45°-60°C range and contains about 82 percent endo-exo isomer of 1,2,3,-4,10,10-hexachloro-1,4,5,8-diendomethylene-1,4,4a,5,8,8a-hexahydronaphthalene, 12-13 percent analogs, and about 5 percent various other compounds. Commercial-scale production of aldrin is a semicontinuous process involving reaction between excess bicyclo [2.2.1] heptadiene-2,5 and hexachlorocyclopentadiene at 100°C. The aldrin yield is about 80 percent based on the hexachlorocyclopentadiene. The excess bicycloheptadiene is recovered and reused. Bicycloheptadiene may be purchased from outside or produced on-site by the reaction of cyclopentadiene with acetylene at 250-360°C and 400-2000 kilonewtons/square meter (60-300 psi) pressure. The reaction is carried out either in an organic solvent (e.g., pentane) or with nitrogen as a diluent for acetylene. The yield of bicycloheptadiene is about 30-60 percent with toluene, tricycline and a number of other compounds formed as byproducts. Acetylene used in aldrin production is generally produced on site from calcium carbide (process yield is estimated at 95 percent). Hexachlorocyclopentadiene is produced by chlorination of cyclopentadiene which can be obtained from cracking of dicyclopentadiene. Production of chemical aldrin can be summarized as follows:

$$CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2$$

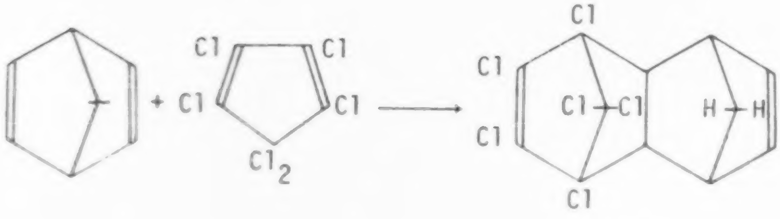
$$C_{10}H_{12} \xrightarrow{\text{Cracking}} C_5H_6$$



Hexachlorocyclopentadiene



Bicycloheptadiene



Aldrin

Figure 5-23 presents a schematic flow diagram for the production of aldrin, based on data reported by Lawless, et al.(41) A typical plant size is approximately 4,500 metric tons per year. The mass balance data were estimated based on the production chemistry discussed above. The major land-destined wastes from the process are lime sludge from acetylene production (estimated at 0.73 kg of $Ca(OH)_2$ per kg of technical grade aldrin), tars from production of bicycloheptadiene and cyclopentadiene (estimated at a total of 0.5 kg/kg of product), damaged containers containing aldrin, and chemical spills. No liquid process waste containing aldrin is generated. Wastewater from floor washing and spill clean-up, however, would contain some aldrin.

Atrazine(41, 52)

Atrazine is a selective herbicide of the triazine class. Production of atrazine in 1972 was 41,000 metric tons (90 million pounds).(42) It is a white crystalline substance with a melting point of 173-175°C and a water

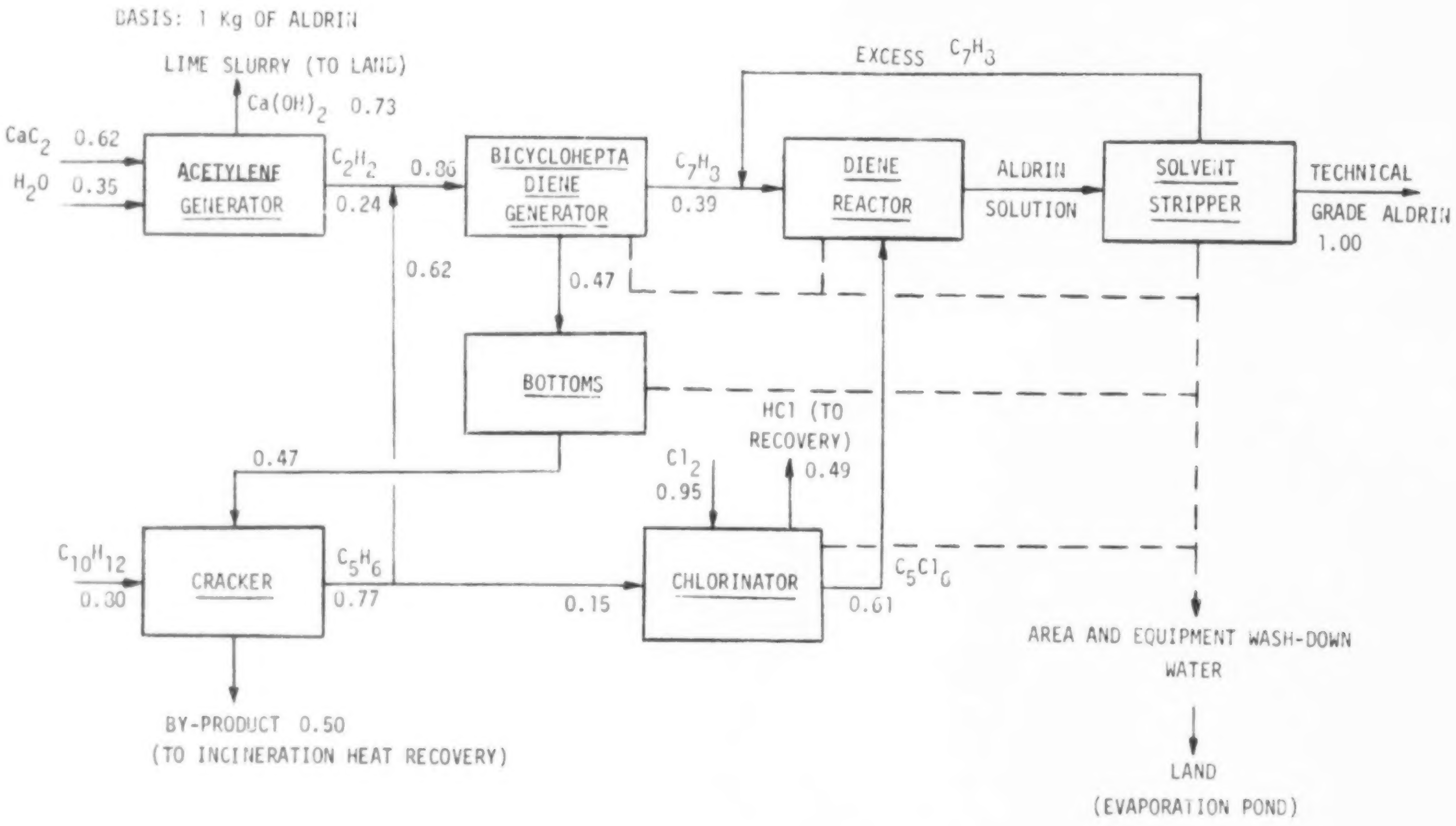
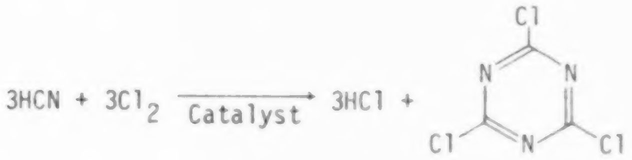

BASIS: 1 Kg OF ALDRIN
LIME SLURRY (TO LAND)
Ca(OH)2 0.73
CaC2 0.62
H2O 0.35
ACETYLENE GENERATOR
C2H2 0.24
0.86
0.62
BICYCLOHEPTA DIENE GENERATOR
C7H3 0.39
0.47
BOTTOMS
0.47
EXCESS C7H3
DIENE REACTOR
ALDRIN SOLUTION
SOLVENT STRIPPER
TECHNICAL GRADE ALDRIN 1.00
C10H12 0.30
CRACKER
C5H6 0.77
0.15
BY-PRODUCT 0.50 (TO INCINERATION HEAT RECOVERY)
Cl2 0.95
HCl (TO RECOVERY) 0.49
CHLORINATOR
C5Cl6 0.61
AREA AND EQUIPMENT WASH-DOWN WATER
LAND (EVAPORATION POND)

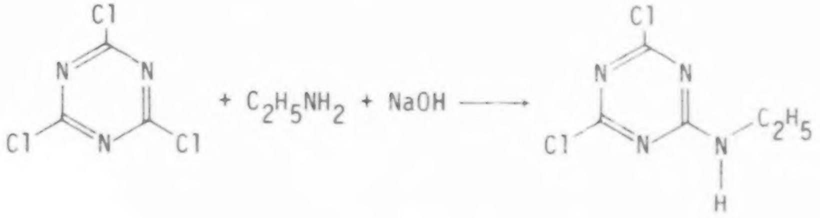
Figure 5-23. Aldrin Manufacture

solubility of less than 0.01 percent. The major producer in the United States was Ciba-Geigy Corp. Atrazine is generally considered to be toxic and environmentally persistent. Toxicity data compiled by Hann and Jensen(53) indicate an aquatic toxicity rating corresponding to a 96-hour TL_m of 1-10 ppm and an LD_{50} (oral rat) in excess of 2000 mg/kg.

Commercial atrazine production is a two-stage operation involving reaction of cyanuric chloride with ethyl amine and sodium hydroxide to produce 2,4-dichloro-6-ethylamino-3-triazine which is then reacted with isopropyl amine and sodium hydroxide to produce atrazine. The cyanuric chloride necessary for the synthesis of triazine can be prepared in a number of ways, including catalytic polymerization of cyanogen chloride (with a yield in excess of 90 percent) using chlorine and hydrogen cyanide as the starting raw material. The polymerization reaction may be carried out in the gas phase at 350-400°C using activated carbon as a catalyst or in the liquid phase under pressure in an organic solvent using either anhydrous aluminum chloride, boron fluoride, or HCl, as catalyst.(47)



Cyanuric Chloride



2,4-dichloro-6-
ethylamino-5-
triazine

+ NaCl + H_2O

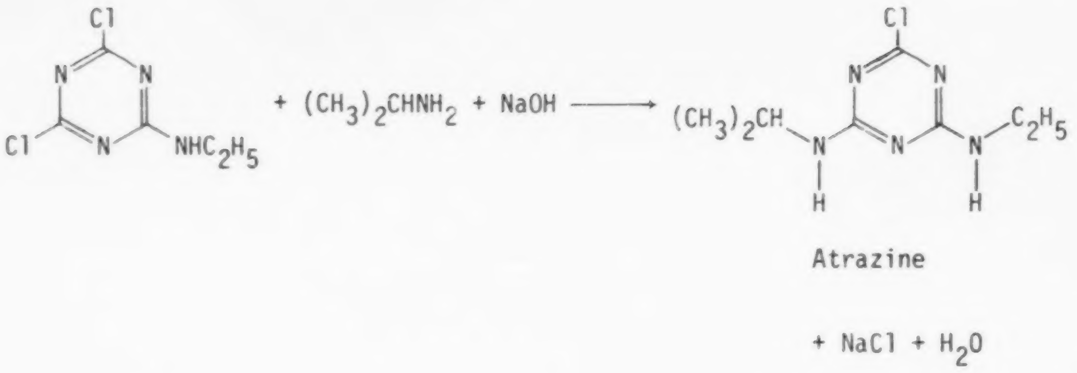


Figure 5-24 is the schematic flow diagram for the production of atrazine by the continuous process, based in part on data reported by Lawless, et al.(41) for a production facility in St. Gabriel, Louisiana. Estimated mass balance data shown on the figure are for the production of 1.00 kg of technical grade atrazine. The 5 percent impurities in the technical grade product are assumed to consist mainly of water insoluble heterocyclic byproducts produced during amination and inorganics such as NaOH and NaCl. Atrazine losses resulting from the filtration step are estimated at 0.1 percent. An efficiency of 90 percent was assumed on the basis of the literature for the production of cyanuric chloride. The data on Figure 5-24 indicate that liquid wastes from atrazine production would be high in salt content and would contain such hazardous constituents as atrazine and cyanide-related compounds. A typical plant size is approximately 20,000 metric tons per year.

Trifluralin(41,42)

Trifluralin is a selective herbicide belonging to the nitroaromatic pesticide class. It is a yellow-orange crystalline substance with a melting point of 48.5-49°C and a water solubility of about 40 ppm. Production estimates for 1972 were 11,000 metric tons (25 million pounds) for the sole manufacturer, Eli Lilly and Company.(43) Trifluralin is considered to be of low toxicity (LD_{50} is greater than 10,000 mg/kg) and environmentally nonpersistent. Production of trifluralin involves nitration of p-chlorobenzotrifluoride followed by amination with dipropyl amine:

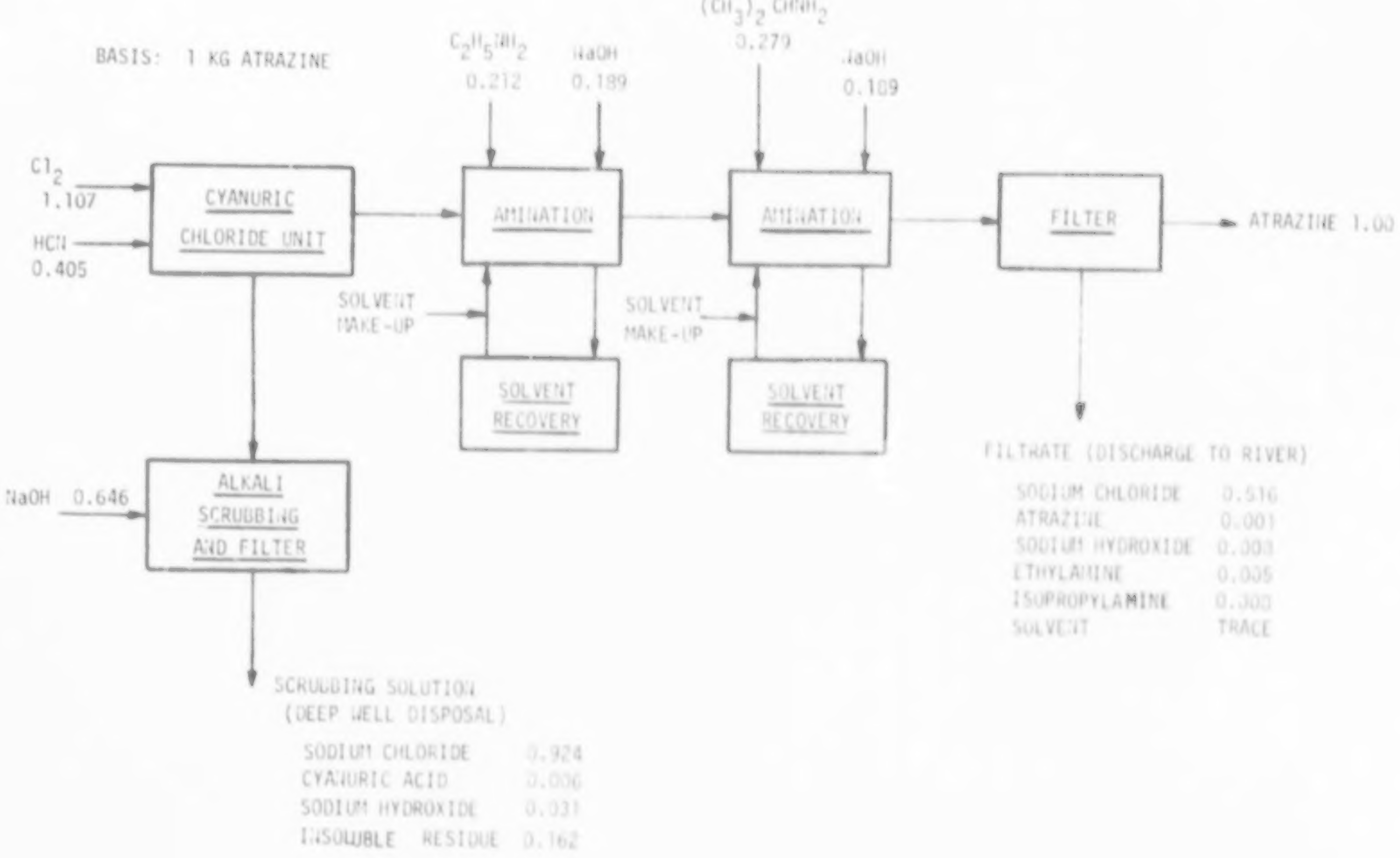

BASIS: 1 KG ATRAZINE
Cl_2 1.107
HCN 0.405
CYANURIC CHLORIDE UNIT
$C_2H_5NH_2$ 0.212
NaOH 0.189
AMINATION
SOLVENT MAKE-UP
SOLVENT RECOVERY
$(CH_3)_2CHNH_2$ 0.279
NaOH 0.109
AMINATION
SOLVENT MAKE-UP
SOLVENT RECOVERY
FILTER
ATRAZINE 1.00
FILTRATE (DISCHARGE TO RIVER)
SODIUM CHLORIDE 0.516
ATRAZINE 0.001
SODIUM HYDROXIDE 0.003
ETHYLAMINE 0.005
ISOPROPYLAMINE 0.300
SOLVENT TRACE
NaOH 0.646
ALKALI SCRUBBING AND FILTER
SCRUBBING SOLUTION (DEEP WELL DISPOSAL)
SODIUM CHLORIDE 0.924
CYANURIC ACID 0.006
SODIUM HYDROXIDE 0.031
INSOLUBLE RESIDUE 0.162

Figure 5-24. Atrazine Manufacture

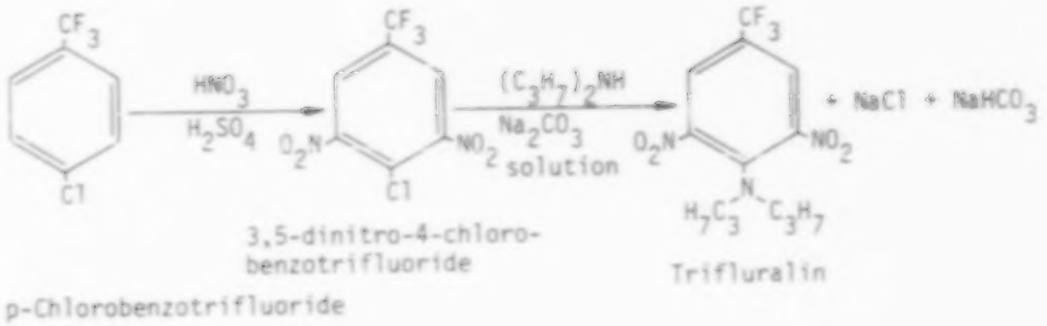


Figure 5-25 is the schematic flow diagram for the production of trifluralin, based in part on discussions with the technical personnel at Eli Lilly and Company (producer of trifluralin) and data compiled by Lawless, et al.(41) The spent acid (dilute HNO_3/H_2SO_4) from the nitration reaction undergoes denitrification treatment for the recovery of residual nitric acid which is concentrated and returned to the first nitrator. With the exception of a portion which is recycled, the dilute sulfuric acid that is recovered is sold to acid suppliers. Storage and transfer of the intermediate product (3,5-dinitro-4-chlorobenzotrifluoride) is in chloroform, which is recovered from the final product and reused.

Estimated mass balance data for trifluralin production are shown on Figure 5-25. The technical grade trifluralin is assumed to contain 5 percent impurities (consisting mainly of inorganic salts, NaCl, $NaHCO_3$, Na_2CO_3), moisture, and chemical intermediates and side products. The major aqueous wastes from the process are salt water from amination/purification steps and scrubber wastewater from gas cleaning operation. The major pollutants and their relative quantities in the process gas before scrubbing for the Eli Lilly plant in Lafayette, Indiana, are shown in Table 5-16a. The scrubbing system has a pollutant removal efficiency in excess of 90 percent. Typical analysis of the brine waste from this plant before and after waste treatment by activated carbon adsorption is also shown in Table 5-16b. Because the production data and wastewater volumes were not available, the data in Tables 5-15 and 5-16 cannot be expressed in terms of waste generation factors to check the accuracy of the calculated mass balance data shown on Figure 5-25. At this plant, the spent carbon from waste brine treatment is currently stored in plastic-lined steel drums. The effluent liquids from

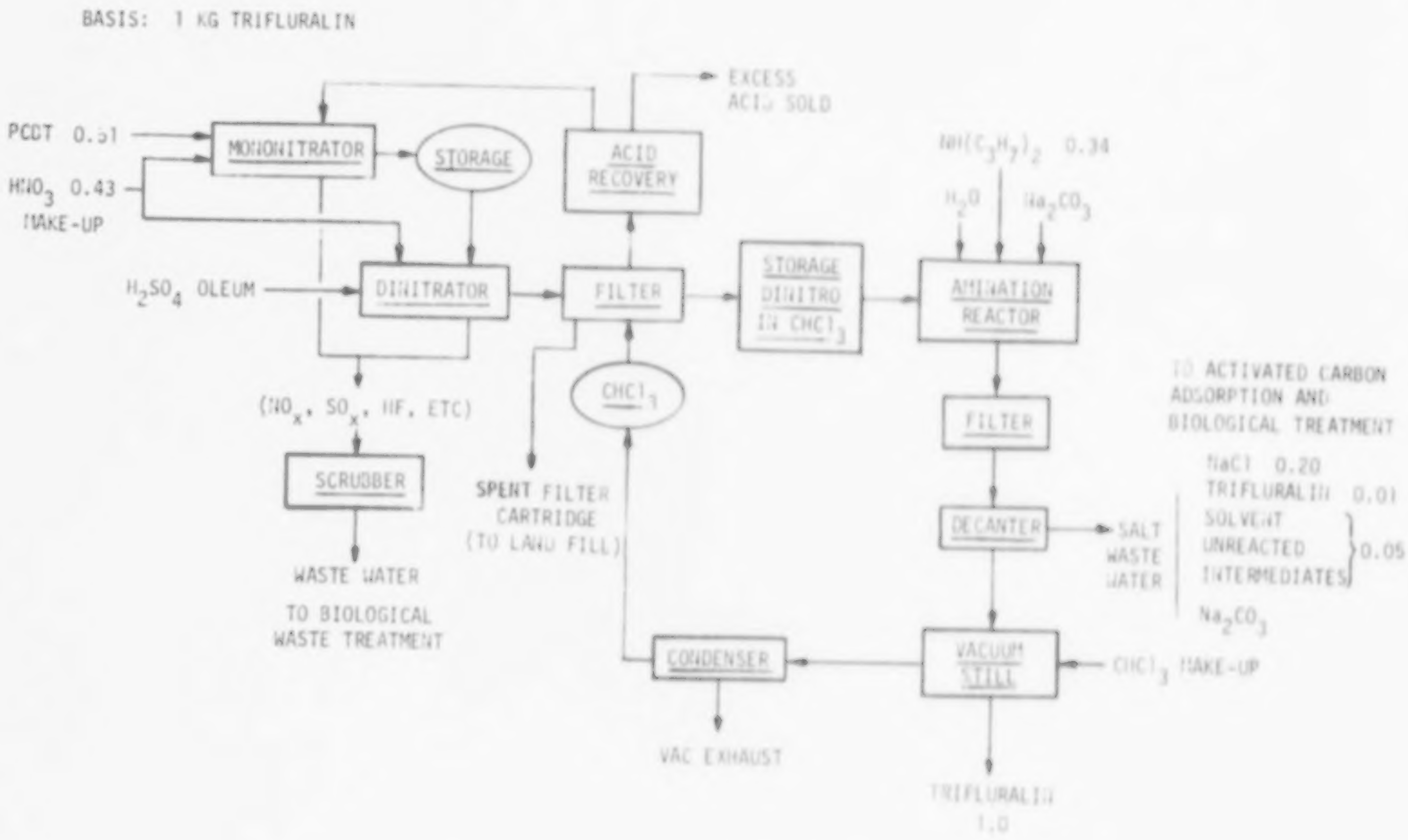

BASIS: 1 KG TRIFLURALIN
PCDT 0.51
HNO_3 0.43
MAKE-UP
MONONITRATOR
STORAGE
ACID RECOVERY
EXCESS ACID SOLD
H_2SO_4 OLEUM
DINITRATOR
FILTER
STORAGE DINITRO IN $CHCl_3$
$NH(C_3H_7)_2$ 0.34
H_2O
Na_2CO_3
AMINATION REACTOR
(NO_x, SO_x, HF, ETC)
SCRUBBER
WASTE WATER
TO BIOLOGICAL WASTE TREATMENT
$CHCl_3$
SPENT FILTER CARTRIDGE (TO LAND FILL)
FILTER
TO ACTIVATED CARBON ADSORPTION AND BIOLOGICAL TREATMENT
DECANTER
SALT WASTE WATER
NaCl 0.20
TRIFLURALIN 0.01
SOLVENT
UNREACTED
INTERMEDIATES
0.05
Na_2CO_3
CONDENSER
VACUUM STILL
$CHCl_3$ MAKE-UP
VAC EXHAUST
TRIFLURALIN 1.0

Figure 5-25. Trifluralin Manufacture

Table 5-16a. Trifluralin Production — Process Exhaust Before Scrubbing

Compounds Emitted	Particulates	Gases
Sulfur Dioxide	--	<1.5 kg/hr (< 3 lb/hr)
Sulfur Trioxide	--	<0.5 kg/hr (< 1 lb/hr)
Hydrogen Fluoride	--	<0.5 kg/hr (< 1 lb/hr)
Hydrogen Chloride	--	<4.5 kg/hr (<10 lb/hr)
Nitrogen Oxides	--	<1.5 kg/hr (< 3 lb/hr)
Nitrate	<0.5 kg/hr (<1 lb/hr)	--
Sulfate	<0.5 kg/hr (<1 lb/hr)	--
Chloride	<0.5 kg/hr (<1 lb/hr)	--

Table 5-16b. Analysis of Typical Aqueous Brine from Trifluralin Manufacture Before and After Treatment with Activated Carbon

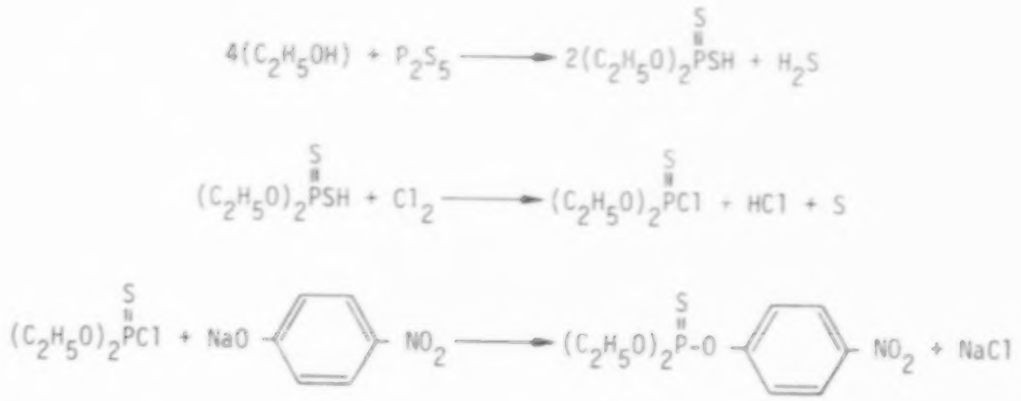
	Raw Waste	Treated Waste
Color, units	100,000	1,000
COD, ppm	14,000	1,200
Fluoride, ppm	1,000	75
pH	9	8

gas scrubbing and carbon adsorption units are treated in a biological waste treatment system before final disposal.

Parathion and Methyl Parathion

Parathion (O,O-diethyl O-p-nitrophenyl phosphorothioate) and methyl parathion (O,O-dimethyl O-p-nitrophenyl phosphorothioate) are two of the most widely used organophosphate insecticides. Annual production capacity in 1973 for the parathions was estimated at 62,000 metric tons (137 million pounds).(11) There were six major producers in 1973: American Cyanamid Company, Hercules Incorporated, Kerr-McGee Corporation, Monsanto Company, Stauffer Chemical Company, and Vicksburg Chemical Company. Production facility sizes ranged from 6,000 to 23,000 metric tons per year capacity.

Because of its lower toxicity to mammals, methyl parathion is gradually displacing parathion and is currently produced in a larger quantity. Except for the use of ethanol instead of methanol as one of the starting raw materials, the industrial synthesis of parathion is essentially identical to that for methyl parathion. The synthesis of parathion involves (1) reaction of phosphorus pentasulfide with ethanol to produce diethyl dithiophosphoric acid, (2) chlorination of diethyl dithiophosphoric acid to obtain diethylchlorothiophosphate, and (3) reaction of diethylchlorothiophosphate with sodium p-nitro phenolate in an organic solvent (e.g., acetone) to produce parathion:



$$4(C_2H_5OH) + P_2S_5 \longrightarrow 2(C_2H_5O)_2\overset{S}{\overset{\|}{P}}SH + H_2S$$

$$(C_2H_5O)_2\overset{S}{\overset{\|}{P}}SH + Cl_2 \longrightarrow (C_2H_5O)_2\overset{S}{\overset{\|}{P}}Cl + HCl + S$$

Table 5-17 presents some general characteristic data for parathion and methyl parathion. The schematic process flow diagram and estimated mass balance data for a parathion production plant are shown in Figure 5-26. At this plant the by-product hydrogen sulfide gas is flared, and the sulfur generated in the chlorinator is disposed of by incineration. Part of the hydrochloric acid produced in the chlorinator is recovered and the rest is neutralized with sodium carbonate and discharged to the biological waste treatment plant. Sodium chloride (possibly containing small quantities of the product and chemical intermediates) is in the waste stream from the parathion unit which is

Table 5-17. Some General Characteristics of Parathion and Methyl Parathion(47,53)

	Parathion	Methyl Parathion
Physical nature (pure substance)	Clear oily liquid	White crystalline substance
(technical grade)	Dark brown liquid	–
Melting point, °C	6.1	35-36
Boiling point, °C	113*	109*
Solubility in water, ppm	24	55
LD_{50}, mg/kg	6-12	25-50
96-hr TL_m, ppm	<1	<1
Environmental persistence	Nonpersistent**	Nonpersistent**
Purity of technical grade, %	98	96-98
Main organic impurities in the technical grade	O-ethyl O,O-bis (4-nitrophenyl) thiophosphate; p-nitrophenol; triethyl thiophosphate	O-methyl O,O-bis (4-nitrophenyl) thiophosphate; p-nitrophenol; trimethylthiophosphate

*At 7 newtons/meter^2 (0.05 mm of Hg)

**Persistent in soil 1 to 3 months (90)

also discharged to the plant waste treatment system. Parathion concentration in the effluent from the biological treatment system is reported to be less than 1 ppm.

Malathion(41,47,52)

Malathion is a nonsystemic organophosphate insecticide and acaricide.* The pure substance is a colorless liquid with a boiling point of 150°C and a water solubility of 145 mg per liter (at 20°C). The technical grade product is a brownish liquid of 95-98% purity. Malathion is considered to be of "low" toxicity and environmentally nonpersistent. The LD_{50} reported for various experimental animals is in the 500-1500 mg/kg range.(47) The aquatic toxicity rating for malathion corresponds to a 96-hour TL_m of less than 10 ppm.(52)

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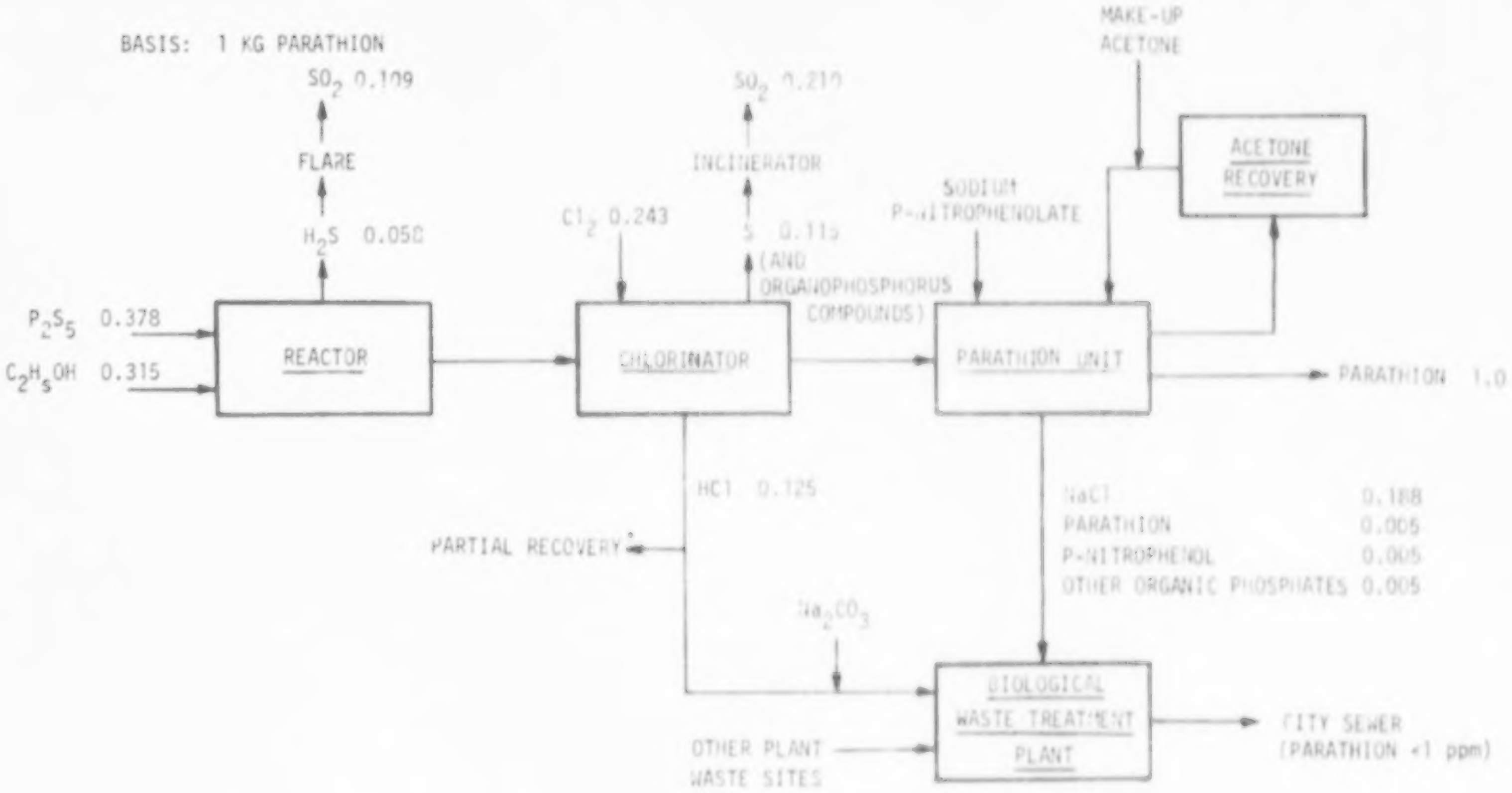
*A type of pesticide having the power to kill acarids (i.e., mites and ticks)

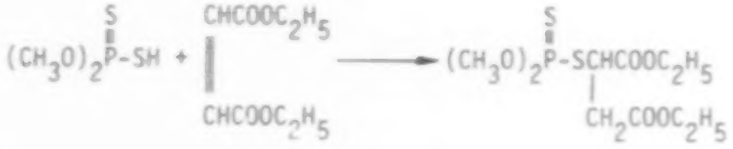

BASIS: 1 KG PARATHION
SO_2 0.109
FLARE
H_2S 0.050
P_2S_5 0.378
C_2H_5OH 0.315
REACTOR
Cl_2 0.243
SO_2 0.210
INCINERATOR
S 0.115
(AND ORGANOPHOSPHORUS COMPOUNDS)
CHLORINATOR
HCl 0.125
PARTIAL RECOVERY*
Na_2CO_3
SODIUM P-NITROPHENOLATE
MAKE-UP ACETONE
ACETONE RECOVERY
PARATHION UNIT
PARATHION 1.0
NaCl 0.188
PARATHION 0.005
P-NITROPHENOL 0.005
OTHER ORGANIC PHOSPHATES 0.005
OTHER PLANT WASTE SITES
BIOLOGICAL WASTE TREATMENT PLANT
CITY SEWER (PARATHION <1 ppm)

* APPROXIMATELY 80 PERCENT RECOVERY AS 32 PERCENT BY WEIGHT HCl IN WATER

Figure 5-26. Parathion Manufacture

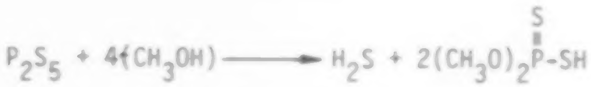
Malathion capacity reported for 1972 was 14,000 metric tons (30 million pounds) per year.(42) The manufacturers reported were American Cyanamid Company, Blue Spruce Company, and Prentiss Drug and Chemical Company.

Commercial production of malathion involves the addition of dimethyldithiophosphoric acid to diethylmaleate. The reaction is usually conducted in an organic solvent and in the presence of a proprietary basic catalyst:



$$(CH_3O)_2\overset{S}{\overset{\|}{P}}\text{-}SH + \begin{array}{l} CHCOOC_2H_5 \\ \| \\ CHCOOC_2H_5 \end{array} \longrightarrow (CH_3O)_2\overset{S}{\overset{\|}{P}}\text{-}\begin{array}{l} SCHCOOC_2H_5 \\ \;| \\ CH_2COOC_2H_5 \end{array}$$

The dimethyldithiophosphoric acid required for malathion synthesis is obtained by the reaction of methanol with phosphorus pentasulfide:



$$P_2S_5 + 4(CH_3OH) \longrightarrow H_2S + 2(CH_3O)_2\overset{S}{\overset{\|}{P}}\text{-}SH$$

Impurities (2-5 percent) in the technical grade malathion include trimethyldithiophosphate, diethylmaleate, and residual solvent. The hydrogen sulfide gas generated in the reaction of phosphorus pentasulfide with methanol is generally processed for sulfur recovery.

A schematic flow diagram, including estimated mass balance for the production of malathion, is shown in Figure 5-27. The technical grade malathion was assumed to contain 3 percent impurities consisting primarily of diethylmaleate, trimethyldithiophosphoric acid and toluene.(47) The flow diagram shown is from Lawless, Rumker and Ferguson(41) for a plant where the liquid process wastes are barged to the sea.* Solid wastes from the filtration step are disposed of in an approved landfill. The hydrogen sulfide-containing product gas is processed for sulfur recovery. The total hazardous constituents of the wastes are estimated at 0.084 kg per kg of technical grade product.

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*Ocean disposal regulations will probably forbid continuation of this practice and require a change to land-based treatment and disposal techniques.

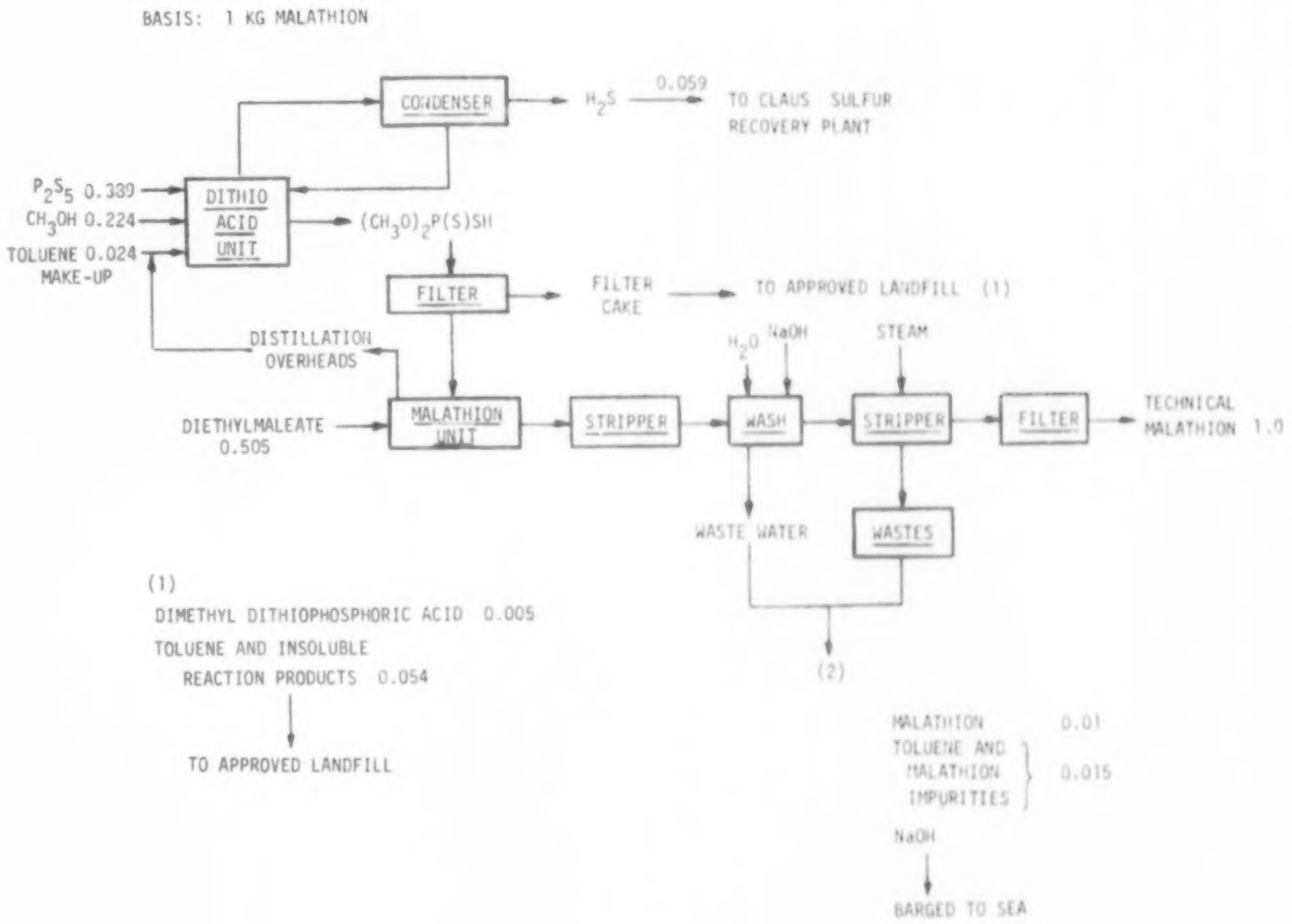
BASIS: 1 KG MALATHION
CONDENSER
H_2S 0.059
TO CLAUS SULFUR RECOVERY PLANT
P_2S_5 0.339
CH_3OH 0.224
TOLUENE 0.024 MAKE-UP
DITHIO ACID UNIT
$(CH_3O)_2P(S)SH$
FILTER
FILTER CAKE
TO APPROVED LANDFILL (1)
DISTILLATION OVERHEADS
H_2O
NaOH
STEAM
DIETHYLMALEATE 0.505
MALATHION UNIT
STRIPPER
WASH
STRIPPER
FILTER
TECHNICAL MALATHION 1.0
WASTE WATER
WASTES
(1)
DIMETHYL DITHIOPHOSPHORIC ACID 0.005
TOLUENE AND INSOLUBLE REACTION PRODUCTS 0.054
TO APPROVED LANDFILL
(2)
MALATHION 0.01
TOLUENE AND MALATHION IMPURITIES 0.015
NaOH
BARGED TO SEA

Figure 5-27. Malathion Manufacture

5.3.2 Annual Process Stream Discharge to Land Disposal

Total Quantities

The estimated total quantities to land of process wastes, hazardous wastes, hazardous components, and highly dangerous components for the pesticides industries are presented in Tables 5-18, 5-19, and 5-20. The general procedures used were those cited in Section 3 and Appendix A. More specifically, based on the data available in the literature and information obtained through site visits and discussions with technical personnel in the industry, estimates were made of the waste generation factors for "land-destined" wastes for each of the 32 pesticides selected to represent the 17 pesticide groups of SIC 28694. In cases where more than one pesticide was used to represent a pesticide class, the waste factor for the class was calculated as the average of the waste factors for the class representatives. These class waste factors were then used to estimate waste quantities for each class and the total waste generated in the pesticide manufacturing industry (SIC 28694). Estimates of waste quantities for 1977 and 1983 were based on assumed production increases of 10 percent (over 1973) and 21.6 percent (over 1983), respectively,* and consideration of potential impacts of the Federal Air and Water Pollution Control laws. In evaluating such impacts, inputs were solicited from industry and their responses were considered in estimating future waste quantities.

The "land destined" waste quantities for the pesticide formulation industry (SIC 2879) were assumed to be 0.0033 kg of waste per kg of production.(28) The wastes were assumed to have the average composition of the pesticide formulations,(28) which contained about 40 percent active ingredients. This value for the weighted average composition was obtained by determining, from Table 4-7, the ratio between the total production of technical organic pest control chemicals (SIC 28694) and the total production of pesticide preparations and formulations (SIC 2879).

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*The basis for the production increases assumed were the increases in gross national product projected from the data published by the United California Bank.(51)

Table 5-18. Process Waste Discharge* to Land Disposal, Metric Tons for CY 1973, by Type and Standard Industrial Classification, Pesticides Industries

EPA Region	State	Total Process Waste Streams		Hazardous Waste Streams		Hazardous Components		Highly Dangerous Components	
		SIC 28694	SIC 2879	SIC 28694	SIC 2879	SIC 28694	SIC 2879	SIC 28694	SIC 2879
4	Alabama	35153	88	35153	88	15508	35	9837	21
10	Alaska								
9	Arizona		11		11		4		1
6	Arkansas	3892	88	3892	88	664	35	582	27
9	California	16753	580	16753	580	3258	231	2780	139
8	Colorado	794	88	794	88	386	35	52	21
1	Connecticut	642	22	642	22	24	9	11	5
3	Delaware		11		11		4		1
3	District of Columbia								
4	Florida	93	274	93	274	93	110		66
4	Georgia	489	153	489	153	19	61	9	37
9	Hawaii		11		11		4		1
10	Idaho		11		11		4		1
5	Illinois	5299	197	5299	197	965	79	336	47
5	Indiana	190	55	190	55	36	22	32	13
7	Iowa	4245	110	4245	110	562	44	417	26
7	Kansas	3214	33	3214	33	290	13	254	8
4	Kentucky		11		11		4		1
6	Louisiana	22229	165	22229	165	10283	66	8227	40
1	Maine								
3	Maryland	255	66	255	66	256	26	4	16
1	Massachusetts		66		66		26		16
5	Michigan	7574	55	7574	55	1804	22	1353	13
5	Minnesota	90	44	90	44	71	18	38	11
4	Mississippi	6982	11	6982	11	2597	3	2116	1
7	Missouri	5241	252	5241	252	4073	101	521	61
8	Montana		22		22		9		5
7	Nebraska		33		33		13		8
9	Nevada		22		22		9		5
1	New Hampshire		11		11		4		1
2	New Jersey	19629	165	10763	165	5465	66	2361	40
6	New Mexico								
2	New York	1161	198	1157	198	210	74	193	49
4	North Carolina	109	131	109	131	0.1	52	0.1	32
8	North Dakota								
5	Ohio	1732	142	1732	142	96	57	46	25
6	Oklahoma		33		33		13		8
10	Oregon	1524	55	1524	55	290	22	254	13
3	Pennsylvania	407	165	407	165	148	66	22	40
2	Puerto Rico		44		44				
1	Rhode Island								
4	South Carolina	136	99	136	99	55	40	53	24
8	South Dakota								
4	Tennessee	6432	99	6432	99	2548	40	2291	24
6	Texas	18687	383	14463	383	5739	153	4461	92
8	Utah		11		11		4		3
1	Vermont								
3	Virginia	18	44	18	44	0.1	18	0.1	11
10	Washington	2449	88	2449	88	552	35	499	21
3	West Virginia		11		11		4		3
5	Wisconsin	5248	55	567	55	91	22	79	13
8	Wyoming								
NATIONAL TOTAL		177,853	4,159	153,733	4,159	56,161	1,638	35,316	1,003

REGION TOTALS								
1	642	99	8470	99	24	40	11	25
2	20790	351	11920	351	5675	142	2554	89
3	680	297	680	297	404	120	37	75
4	49394	868	49394	868	20898	351	14306	221
5	20129	548	15468	548	3063	222	2290	140
6	44967	669	40689	669	16686	271	13181	170
7	12700	428	12700	428	4925	173	1192	109
8	794	121	794	121	386	49	52	31
9	16753	628	16753	624	3258	253	2780	159
10	3973	154	3973	154	842	62	753	39

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*Estimated, water-free basis, using the procedures given in Section 3, Section 5.3.2, and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3-6, 10, 11, 37, 41, 42, 52-55.

Table 5-19. Process Waste Discharge* to Land Disposal, Metric Tons for CY 1977, by Type and Standard Industrial Classification, Pesticides Industries

EPA Region	State	Total Process Waste Streams		Hazardous Waste Streams		Hazardous Components		Highly Dangerous Components	
		SIC 28694	SIC 2879	SIC 28694	SIC 2879	SIC 28694	SIC 2879	SIC 28694	SIC 2879
4	Alabama	42668	97	42668	97	21127	36	14260	25
10	Alaska								
9	Arizona		12		12		5		3
6	Arkansas	3841	97	3841	97	730	39	640	23
9	California	18591	638	18591	638	3695	255	3153	153
8	Colorado	978	98	978	97	543	39	58	23
1	Connecticut	1247	24	1247	24	135	10	24	
3	Delaware		12		12		5		3
3	District of Columbia								
4	Florida	122	301	122	301	122	122	20	23
4	Georgia	500	168	500	168	23	64	30	31
9	Hawaii		12		12		5		3
10	Idaho		12		12		5		3
5	Illinois	5952	217	5952	217	1599	88	825	32
5	Indiana	211	60	211	60	41	24	35	13
7	Iowa	6249	121	6249	121	1427	49	421	22
7	Kansas	1676	36	1676	36	339	16	273	4
4	Kentucky		12		12		5		2
6	Louisiana	26036	181	26036	181	12325	71	2830	46
1	Maine								
3	Maryland	361	73	361	73	361	82	28	23
1	Massachusetts		73		73		30		23
5	Michigan	9823	60	9823	60	2248	23	1512	32
5	Minnesota	191	48	191	48		13	20	12
4	Mississippi	10425	14	10425	14	4077	4	5584	4
7	Missouri	9153	277	9153	277	5750	112	1776	32
8	Montana		24		24		10		3
7	Nebraska		36		36		13		3
9	Nevada		24		23		12		6
1	New Hampshire		12		12		5		3
2	New Jersey	25027	182	15281	182	9347	74	[illegible]	87
6	New Mexico								
2	New York	1418	204	1418	204	432	82	102	11
4	North Carolina	159	144	159	143	7	58	7	26
8	North Dakota								
5	Ohio	2571	156	2571	156	342	62	145	42
6	Oklahoma		36		36		15		2
10	Oregon	1676	60	1676	60	219	28	325	25
3	Pennsylvania	527	182	527	182	192	23	27	41
2	Puerto Rico								
1	Rhode Island								
4	South Carolina	221	109	221	109	121	44	138	29
8	South Dakota								
4	Tennessee	9499	109	9499	109	5226	44	4336	136
6	Texas	25243	421	20602	421	11013	180	9296	107
8	Utah		12		12		5		3
1	Vermont								
3	Virginia	26	48	26	48	1	12	[illegible]	11
10	Washington	2844	97	2844	97	907	35	515	15
3	West Virginia		12		12		5		3
5	Wisconsin	5761	60	656	60	107	24	87	31
8	Wyoming								
NATIONAL TOTALS		211,896	4,575	192,404	4,575	83,676	1,870	58,557	1,117

REGION TOTALS								
1	1247	109	1247	109	135	44	24	26
2	26445	386	16699	386	9779	156	5788	98
3	914	327	914	327	554	132	126	83
4	63594	955	63594	955	27413	388	26442	243
5	27409	603	18304	603	4017	244	2893	153
6	55120	736	50479	736	24068	297	12756	102
7	17078	471	17078	471	7554	190	2487	119
8	978	133	978	133	543	54	58	24
9	18591	686	18591	686	3695	277	3153	174
10	4520	169	4530	169	1126	68	840	43

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*Estimated, water-free basis, using the procedures given in Section 3, Section 5.3.2, and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3-6, 10, 11, 37, 41, 47, 51-55.

Table 5-20. Process Waste Discharge* to Land Disposal, Metric Tons for CY 1983, by Type and Standard Industrial Classification, Pesticides Industries

		Total Process Waste Streams		Hazardous Waste Streams		Hazardous Components		Highly Dangerous Components	
EPA Region	State	SIC 2869	SIC 2879	SIC 2869	SIC 2879	SIC 2869	SIC 2879	SIC 2869	SIC 2879
4	Alabama	47162	107	47162	107	23155		16316	22
10	Alaska								
9	Arizona		13		13		6		3
6	Arkansas	4246	107	4246	107	807	43	707	25
9	California	20551	702	20551	702	4085	290	3408	168
8	Colorado	1081	97	1081	107	600	43	64	21
1	Connecticut	1378	27	1378	27	149	11	27	7
3	Delaware		13		13		6		3
3	District of Columbia								
4	Florida	135	331	135	331	135	134	22	90
4	Georgia	553	185	553	185	26	25	11	45
9	Hawaii		13		13		6		3
10	Idaho		13		13		6		3
5	Illinois	6580	239	6580	239	1191	47	1017	61
5	Indiana	233	66	233	66	45	26	23	10
7	Iowa	6908	183	6908	183	833	54	480	28
7	Kansas	1853	40	1853	40	252	26	203	10
4	Kentucky		13		13		5		3
6	Louisiana	28782	183	28782	183	13625	86	3444	[illegible]
1	Maine								
3	Maryland	399	80	399	80	398	22	62	23
1	Massachusetts		80		80		22		21
5	Michigan	8531	94	8531	94	2281	26	2036	9
5	Minnesota	211	53	211	53	183	6	23	3
4	Mississippi	13524	55	13524	55	4282	[illegible]	4063	3
7	Missouri	10279	305	10279	305	6261	122	2069	[illegible]
8	Montana		22		22		[illegible]		[illegible]
7	Nebraska		40		40		26		[illegible]
9	Nevada		29		29		[illegible]		[illegible]
1	New Hampshire		13		13		6		3
2	New Jersey	27666	200	16893	200	10533	81	6135	51
6	New Mexico								
2	New York	1567	226	1567	226	478	91	262	57
4	North Carolina	176	158	176	158	78	64	[illegible]	92
8	North Dakota								
5	Ohio	2952	172	2952	172	494	62	75	44
6	Oklahoma		40		40		26		12
10	Oregon	1853	66	1853	66	252	28	203	10
3	Pennsylvania	583	200	583	200	212	81	125	52
2	Puerto Rico		NA						
1	Rhode Island								
4	South Carolina	244	120	244	120	118	48	121	21
8	South Dakota								
4	Tennessee	10500	120	10500	120	5771	48	5027	31
6	Texas	27305	463	22771	463	11174	187	9471	[illegible]
8	Utah		13		13		6		3
1	Vermont								
3	Virginia	29	53	29	53	3	21	313	12
10	Washington	3144	107	3144	107	992	41	826	29
3	West Virginia		13		13		6		3
5	Wisconsin	6369	66	726	66	118	26	96	4
8	Wyoming								
NATIONAL TOTALS		232,800	5,054	212,664	5,254	93,176	2,067	64,174	1,740

REGION TOTALS								
1	1378	120	1378	120	149	48	27	31
2	29233	425	18460	425	10011	172	6397	108
3	1011	360	929	360	613	145	118	91
4	70294	1050	70294	1050	35603	425	22570	267
5	25876	663	20233	663	5116	260	3195	158
6	60933	810	55903	810	25606	327	19620	206
7	18880	518	18880	518	8394	209	2753	131
8	1081	146	1081	146	1094	59	64	26
9	20551	755	20551	755	4085	305	3408	191
10	4997	186	4997	186	1244	75	932	42

*Estimated, water-free basis, using the procedures given in Section 3, Section 5.3.2, and Appendix A. The data for the calculations were obtained from the private industry sources listed in Table A-1 and References 3-6, 10, 11, 37, 41, 42, 51-55.

The method employed for estimating the waste quantities discharged to land in each state for SIC 2879 (multiplying the waste generation factor cited above by the national production prorated on the basis of the number of establishments in the state) was the best procedure option which could be used with the data available. The data required for the most accurate approach were not available for use. The most accurate approach would have been to obtain and use production information for each pesticide's preparation and formulation facility, summing the individual estimates by geographical area to yield state and regional totals.

The data presented in Table 5-20 indicate the far greater discharge of process wastes to land disposal from the technical pesticides manufacturing portion (SIC 28694) of the pesticides industries. The pesticide preparations and formulations industry (SIC 2879) process waste discharges to land are generally less than 3 percent of those of the technical pesticides industry.

The actual ("wet-basis") volumes of process wastes sent to land disposal by the pesticides industries have been estimated by using the factor 3.17 (see Section 5.2.2 for derivation) for the ratio between wet-basis wastes and dry-weight basis wastes discharged to the land. On this basis, the pesticide industries wet-weight volumes of process wastes to the land were estimated as 554,000 metric tons for 1973, 684,000 metric tons for 1977, and 753,000 metric tons for 1983. The dry weight of the process waste streams has been used as the basis for the estimates presented below for the pesticides industries.

The projected impact on the pesticides industries of changes in waste disposal practices in 1977 to meet the requirements of the Federal Water Pollution Control Act, as amended, is far less, relatively, than the impact projected for the organic chemicals industry. The increase in estimated waste discharge factors (e.g., hazardous waste stream discharge to land for the technical pesticides industries from 0.297 kg per kg of product in 1973 to 0.339 kg per kg of product in 1977) is the best indicator since it eliminates the effect of increases in production. The major reason for the decreased impact of the Act as amended is undoubtedly the extremely high proportion of pesticide industry wastes discharged to the land currently due to the high toxicity of these wastes. Since, generally toxicity had ruled out discharge to water in the past, the amended Act's requirements for removal of hazardous materials from outfalls would not cause the type of increase to land disposal for pesticides that is projected for the organic chemicals industry.

The state which has the highest estimated totals in all process waste discharge categories (total process waste streams, hazardous waste streams, hazardous components, and highly dangerous components) for 1973, 1977, and 1983 is Alabama; Louisiana and New Jersey rank second and third in total process waste discharged to land in 1973. It is anticipated that Louisiana and Texas will rank second and third in 1977 and 1983 in total process waste sent to land.

Louisiana and California discharged the second and third highest totals of hazardous waste streams to land in 1973. In 1977 and 1983, Louisiana and Texas are projected to be second and third highest in hazardous process waste discharges. Louisiana and Texas, whose quantities of hazardous components discharged to land were second and third highest in 1973, are also projected to be second and third in this category of waste discharge in 1977 and 1983. The same states are estimated to have discharged the second and third largest quantities of highly dangerous components to land in 1973. The projections for 1977 and 1983 indicate that Texas will be second and Louisiana third in quantities of highly dangerous components sent to land disposal.

Approximately 90 percent of estimated and projected process wastes discharged to land are classified as hazardous waste streams, for all three years in the study (1973, 1977 and 1983). Approximately 37 percent of the weight (water-free basis) of these hazardous waste streams was composed of hazardous components in 1973. In 1977 and 1983, this quantity will increase to about 43 percent. Highly dangerous components constituted 23 percent of the estimated gross "dry" weight of the pesticide industries' hazardous waste streams in 1973, and will constitute 30 percent of the gross dry weight projected for 1977 and 1983.

Pesticide Formulation(47,48)

Successful use of pesticides depends to a large extent on the formulation of the product into a preparation which can be used directly or can be reformulated and brought most effectively into contact with the target pests in a safe and environmentally acceptable manner. The most important types of formulations are powders, dusts, wettable powders, emulsifiable concentrates, granules, and aerosols. The type of formulation most suitable for a specific application is dependent on a large number of factors, including physicochemical properties and biological efficiency of the active ingredient, host-pest relationship, characteristics of the available production/application equipment, and economic and environmental considerations.

Dusting is frequently the most inexpensive and simplest method for applying pesticides. Pesticidal dusts consist of a physical mixture of active ingredients with fine particles (3-30μ) of an inert carrier/diluent. The concentration of active ingredient may range from 0.1 to 20 percent. The carriers most widely used are organic flour, sulfur, silicon oxides, lime, gypsum, talc, pyrophyllite and bentomite. In making dusts, the ingredients are usually ground in a hammer, impact, vertical roller, or fluid-energy mill.

Wettable powders are solid formulations which can be dispersed in water to produce stable suspensions for more effective application by spraying. A surface active agent (1-2 percent) is usually used to impart wettability and suspendibility of the powder. Wettable powders are usually formulated in a manner similar to that for dust production. Wettable powders, however, are generally more concentrated in the active ingredient (15-95 percent). Emulsifiable concentrates are pesticide formulations which upon dilution with water yield stable emulsions suitable for spraying plants and surfaces. The concentrates are prepared by dissolving the active ingredients (15-80 percent) and a surface active agent (less than 5 percent) in a water-emulsifiable organic solvent. The surface active emulsifiers commonly used include calcium sulfonates, polyethylene and polypropylene glycols, various soaps, and salts of naphthenic acids.

Granulated pesticide formulations are prepared by impregnating granular (0.2-1 mm particle size) inert carriers with liquid pesticides or their solutions. The inert carriers most commonly used include clay, vermiculite, bentomite and diatomaceous earth. The impregnation involves mixing or spraying of the inert granules with the active ingredient in a liquid form. Solid pesticides are usually melted or dissolved in a solvent prior to use.

For applications as aerosols, the active ingredient is commonly dissolved in water or a suitable organic solvent and then packaged with a propellant into various types of pressurized containers. The pesticides solution usually contains less than 2 percent active ingredient and may also contain a number of special purpose additives (e.g., for odor-masking or for enhancing the effectiveness of the active ingredient).

The most important unit operations in pesticide formulation are dry mixing and grinding of solids, dissolving or melting of solids, and blending. Virtually all formulations are batch-type operations. Depending on the location of the site, the operation may be conducted in the open or it may be enclosed within a building. In a formulation plant, the same production equipment is generally used for the formulation of more than one product. The possibility of cross-contamination is a serious problem which can only be minimized by adequate cleaning prior to product "switch-over". A schematic presentation of a typical liquid formulation unit is presented in Figure 5-28.

Wastes from formulation of the pesticides originate from spills, "off-spec" batches, equipment clean-up and mixing and grinding operations. The exact quantity of the waste is affected to a large extent by the in-plant management practices of good housekeeping. As was indicated earlier in this section, the quantity of land-destined wastes generated in the pesticide formulation industry is estimated at 0.0033 kg of waste per kg of production, with the waste containing about 40 percent active ingredients.

5.4 EXPLOSIVES INDUSTRY

As was indicated in Section 4.4.2, explosives-containing wastes originate from the manufacture of basic explosives, from explosives formulation, and from loading, assembling, and packing (LAP) operations. Basic explosives which were manufactured in significant quantities in 1973 were TNT, nitrocellulcse, nitroglycerin, RDX, and HMX. Section 5.4.1.1 contains brief descriptions of the manufacturing process for each of these basic explosives. The production of Composition B, dynamites, and a double-base propellant are described in Section 5.4.1.2 as examples of formulation operations. The description of a typical LAP operation is also presented in Section 5.4.1.3. Quantitative data on land-destined hazardous wastes for the explosives industry are presented in Section 5.4.2.

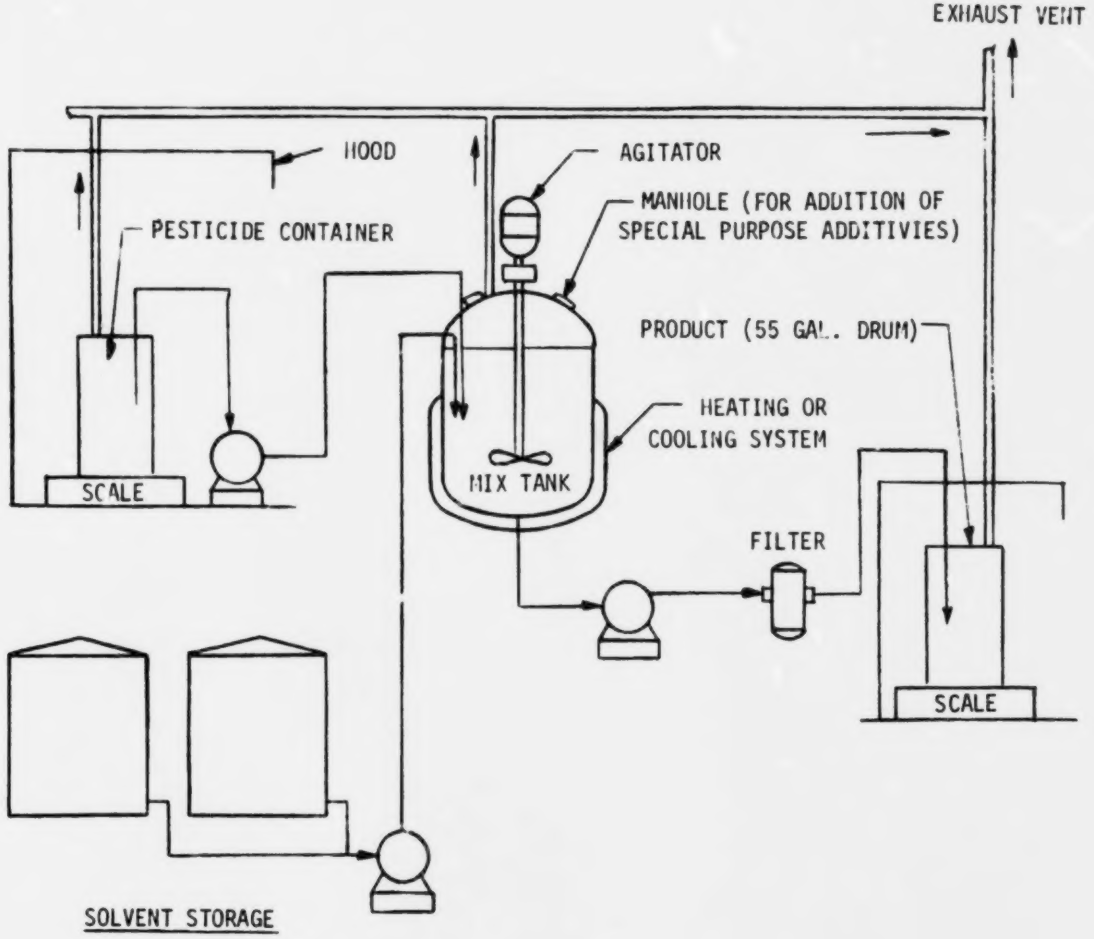
EXHAUST VENT
HOOD
AGITATOR
MANHOLE (FOR ADDITION OF SPECIAL PURPOSE ADDITIVIES)
PESTICIDE CONTAINER
PRODUCT (55 GAL. DRUM)
HEATING OR COOLING SYSTEM
MIX TANK
SCALE
FILTER
SCALE
SOLVENT STORAGE

Figure 5-28. Liquid Formulation Unit

5.4.1 Typical Plant Process and Waste Stream Descriptions

5.4.1.1 Manufacture of Basic Explosives

TNT Production

TNT manufacture involves the nitration of toluene with a mixture of nitric acid and fuming sulfuric acid (oleum). The sulfuric acid acts as a catalyst and a dehydrating agent, absorbing and reacting with the water which is formed by the nitration reactions. The operation may be batch type ("old" technology) or continuous ("new" technology). Although in 1973 both methods were being used for TNT production, plant modernization programs planned for the Army ammunition plants (AAPs) call for replacement of all the remaining existing batch TNT lines with the new Canadian Industries Limited (CIL) continuous TNT lines.

Figure 5-29 is the schematic flow diagram for the batch TNT process and the associated satellite operations.* (The flow diagram is for the Joliet AAP which was the largest TNT producer in 1973). The nitration reactions are carried out in three consecutive batch units referred to as "mono-", "bi-", and "tri-" houses. The feed chemicals to the mono-house are toluene and the waste acid from the bi-house which is fortified with 60% HNO_3. The charge is allowed to settle, the waste acid is transferred to a storage tank (for subsequent recovery), and the partially nitrated toluene (mono oil) is pumped to the bi-house where further nitration is effected in the presence of waste acid from the tri-house fortified with 60% HNO_3. The nitrated product (bi oil) from the bi-house is pumped to the tri-house where the feed acid is a mixture of 98% nitric acid and oleum. The nitrated product from this third-stage operation is crude TNT containing α-TNT (2,4,6-trinitrotoluene) which is the desired product, and TNT isomers which are the impurities. The crude TNT is gravity fed to the wash house for purification.

The purification of crude TNT involves crystallization in water, neutralization of free acid with soda ash and solubilization and removal of undesirable nitrated products by treatment with a solution of sodium sulfite

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*The satellite operations, with the exception of Red Water Disposal, will not be considered in this study. (Red Water Disposal is discussed in Section 6.4.1.)

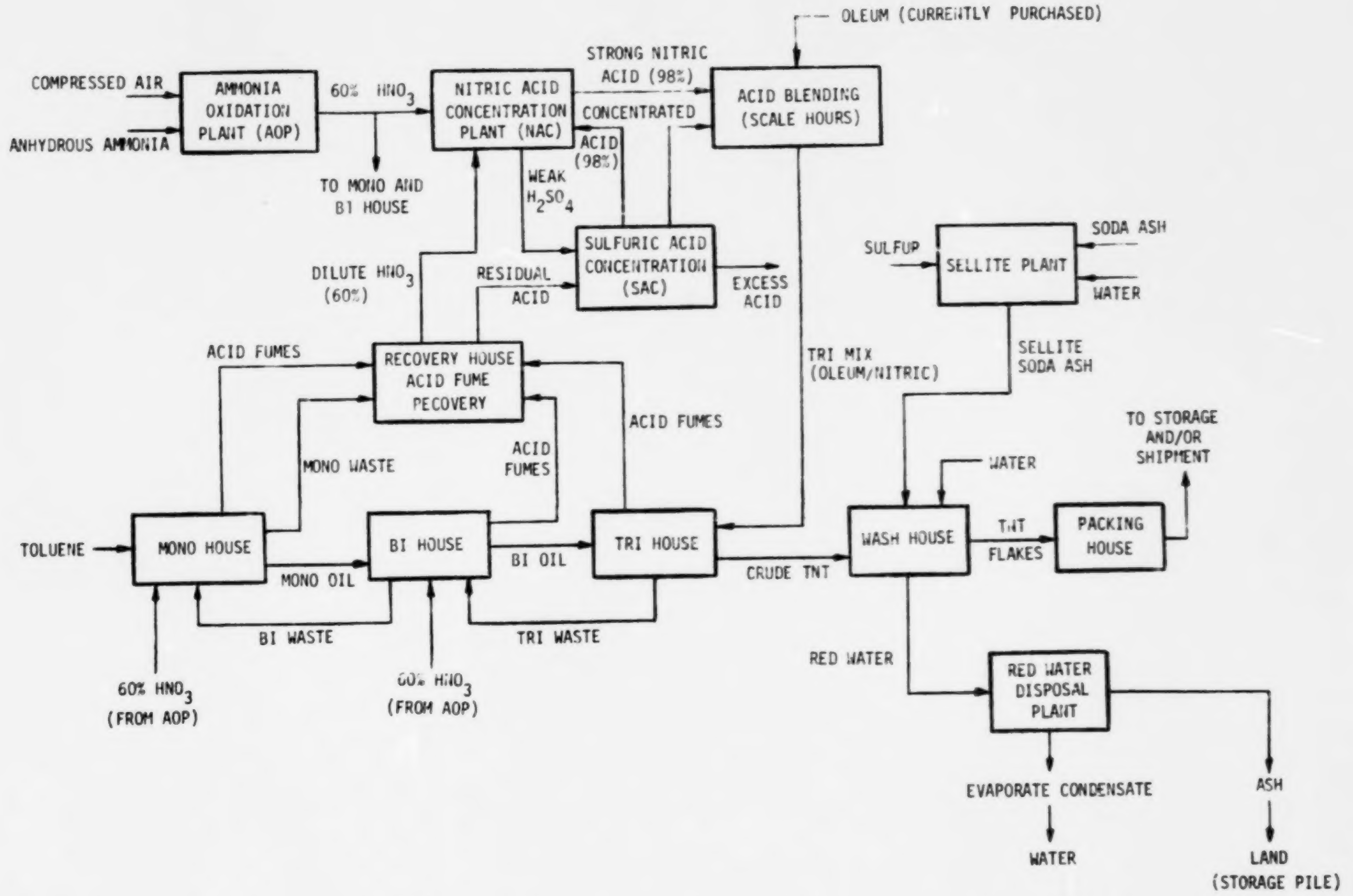
OLEUM (CURRENTLY PURCHASED)
COMPRESSED AIR
ANHYDROUS AMMONIA
AMMONIA OXIDATION PLANT (AOP)
60% HNO_3
TO MONO AND BI HOUSE
NITRIC ACID CONCENTRATION PLANT (NAC)
STRONG NITRIC ACID (98%)
CONCENTRATED
ACID (98%)
WEAK H_2SO_4
ACID BLENDING (SCALE HOURS)
SULFURIC ACID CONCENTRATION (SAC)
EXCESS ACID
DILUTE HNO_3 (60%)
RESIDUAL ACID
SULFUP
SELLITE PLANT
SODA ASH
WATER
SELLITE SODA ASH
ACID FUMES
RECOVERY HOUSE ACID FUME PECOVERY
TRI MIX (OLEUM/NITRIC)
MONO WASTE
ACID FUMES
ACID FUMES
TO STORAGE AND/OR SHIPMENT
WATER
TOLUENE
MONO HOUSE
MONO OIL
BI HOUSE
BI OIL
TRI HOUSE
CRUDE TNT
WASH HOUSE
TNT FLAKES
PACKING HOUSE
BI WASTE
TRI WASTE
RED WATER
RED WATER DISPOSAL PLANT
60% HNO_3 (FROM AOP)
60% HNO_3 (FROM AOP)
EVAPORATE CONDENSATE
ASH
WATER
LAND (STORAGE PILE)

Figure 5-29. Batch Process TNT Manufacturing and Satellite Operations

(sellite). The wastewater from the sellite purification stage is the "red water" which is sent to the red water treatment plant for disposal by evaporation/concentration and concentrate incineration. The TNT slurry is transferred to a filter tank where it is washed and filtered on a screen leaving layers of TNT crystals. The crystals are reslurried with water and pumped to a melt tank where TNT is melted and most of the water is removed by evaporation. The molten product is run into hot air driers for the removal of residual water. The water-free product is solidified on a water-cooled flaker drum and the resultant film is removed in the form of small flakes by scraping with a beryllium blade scraper. The flake TNT is boxed and sent to a packing house for transfer to the magazine storage area.

Continuous TNT lines were in operation at Radford AAP (Va.) in 1973. As of September 1974, when Joliet AAP was visited, three continuous TNT lines were expected to become operational soon and three additional lines were under construction.* In the production of TNT by the continuous process, the nitration of toluene is carried out in six nitrator-separator stages with the organic phase (toluene-nitrobody mixture) flowing countercurrent to the acid phase. Nitric acid fortification is provided at intermediate points in the process. The first and third nitration stages have two nitration vessels per separator, whereas the remaining four stages have only one nitration vessel per separator. Extensive instrumentation provides for safe operation and automatic process control. If the process temperature in a nitrator vessel exceeds a pre-set level, the feed to the nitrator is automatically shut off and the contents of the nitrator and separator are automatically discharged into drowning tubs. For TNT purification, the crude TNT first passes through a mixer-settler washer where five separate countercurrent water washes remove the free acids. The acid wash is returned to the second nitrator as acid make-up. The TNT flows through two sellite washers in series where it is neutralized with soda ash and treated with sodium sulfite. Each of the sellite washers is followed by a separator which separates the aqueous phase (red water) from the purified

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*Flow diagrams for TNT production by the continuous process have not been given due to time and effort constraints.

TNT phase. The dilute red water from the second separator is returned to the first separator, and the more concentrated red water from the first separator is sent to the red water treatment plant. The sellite-treated TNT receives final countercurrent water washes and is slurried and pumped to the finishing building for drying, flaking and packaging.

The major sources of aqueous wastes in TNT manufacturing are red water, spent acids, acid spills, TNT spills, cooling water, and overflows from catch basins and drowning tubs. As indicated in Figure 5-29, the red water is disposed of in the red water treatment plant and the spent acids are treated in the acid recovery facilities. The remaining wastewaters from TNT manufacturing are treated (usually in combination with other plant wastewaters) prior to final disposal. The major objectionable constituents of these wastes are TNT particles, nitrobodies, sulfate, nitrate, acidity (low pH), and color (due to the presence of nitrobodies). The gaseous wastes in the TNT manufacturing are acid fumes which evolve from the nitration and separation vessels. These fumes are withdrawn by the application of a constant suction above the tanks and sent to the fume recovery facility (see Figure 5-29) for treatment/disposal. The solid wastes associated with TNT manufacturing are scrap TNT, and settled TNT sludges collected in sumps in the TNT wash and recovery houses. As discussed in Section 6.4.1, the current disposal method for waste explosives is open-burning.

Table 5-21 presents the material balance for batch TNT production and associated satellite operations. The data are for Joliet AAP and are based on 1969 production and operating conditions. From the standpoint of pollutant discharges to the environment, somewhat lower values would be expected for the present-day operation due to improvements in process control and housekeeping and increased environmental awareness on the part of operating personnel and plant management. Material balance data for the continuous TNT lines are presented in Table 5-22. These data were obtained from Radford AAP (Radford, Va.) which in 1973 operated three CIL continuous TNT lines.

Nitrocellulose (NC) Production

Nitrocellulose is produced by nitration of cellulose (wood pulp or cotton linters). A mixture of nitric and sulfuric acids is used for nitration, with the sulfuric acid acting as a catalyst and dehydrating agent. A block

Table 5-21. Material Balance for TNT Production (Batch Process) and Associated Satellite Operations* (All Values Are Per kg of TNT Manufactured)

Item No.	Process/Operation	Process Input		Process Output		Losses		Discharged To
1	TNT Production	62% HNO_3 Toluene 9[illegible]% HNO_3 10[illegible]% H_2SO_4 (oleum) Na_2SO_3 Na_2CO_3	0.45159 0.42577 [illegible] [illegible] [illegible] [illegible]	Purified TNT 62% HNO_3 returned to process 6[illegible]% H_2SO_4 to SAC Waste product to Red Water Disposal Plant	1.0000 0.35363 [illegible] [illegible]	NO_x fume Nitrobodies [illegible]	0.00646 0.02109 0.06900	Air Air Air (From Sulfuric Acid Concentrators as NO_x)
2	Sellite Production	Sulfur Na_2CO_3	[illegible] [illegible]	Na_2SO_3	[illegible]	Sulfur Sellite	[illegible] [illegible]	Water Water
3	Red Water Plant	Red water solids (14.[illegible]%) [illegible]% H_2SO_4 Steam	[illegible] [illegible] [illegible]	Ash Condensate	[illegible] [illegible]	Ash Condensate	[illegible] [illegible]	Land Water
4	Ammonia Oxidation Plant	Ammonia	Variable depending on product mix	62% HNO_3 to manufacturing To SAC	0.45159 [illegible]	See Item 8		
5	Nitric Acid Concentration	[illegible]% H_2SO_4 [illegible]% HNO_3	[illegible] [illegible]	[illegible]% H_2SO_4 [illegible]% HNO_3	[illegible] [illegible]	See Item 8		
6	Sulfuric Acid Concentrators	[illegible]% H_2SO_4 from NAC [illegible]% H_2SO_4 from TNT process	[illegible] [illegible]	[illegible]% H_2SO_4 To Oleum Plant [illegible] ([illegible])	[illegible] [illegible] [illegible]	See Item 8		
7	Oleum	[illegible]% H_2SO_4 from SAC	[illegible]	[illegible]% H_2SO_4	[illegible]	See Item 8		
8	All Acid Productions (AOP, NAC, SAC, Oleum)	Sulfur (also see process inputs for Items 4-7)	[illegible]	See Items 4-7		NO_x SO_2	[illegible] [illegible]	Air Air

*All acid values are at 100% acid.

Table 5-22. Mass Balance Data for TNT Production by the Continuous Process (Radford AAP, Radford, Virginia)

Process Input kg per kg of TNT		Process Output kg per kg of TNT		TNT/Nitrobody Losses
Toluene	0.48	Purified TNT	1.00	Total: 15% based on toluene feed (6% isomers and α-TNT in red water; 6-8% oxidation products in fume gases; 1-3% isomers and oxidation products in spent acid).
Weak Nitric Acid	0.53	Red Water	0.50	
Strong Nitric Acid	0.80	Spent Acid	3.70	
Oleum	2.5			
Sellite	0.085			

flow diagram of the batch NC production at Radford AAP is presented in Figure 5-30. In the nitrator house, a charge of wood pulp fibers (or cotton linter, depending on the type and grade of NC desired) are treated with a nitric-sulfuric acid mixture. After nitration, the spent acid is removed and crude NC is transferred in the form of a water slurry to the boiling tub house where it is stabilized by an acid boil, two neutral boils and three water washes. In the beater house the NC is cut to desired size. In the poacher house, the NC slurry is pumped into wooden tubs where it receives a neutralization treatment (a soda (sodium carbonate solution) "boil"), three neutral "boils", and three wash cycles. The NC is then screened and transferred to the blender house where NC of various analyses are mixed to produce the specific blend desired. The final purification operation is performed in the wringer house where NC is wrung through centrifugal wringers to obtain a product containing a small and uniform amount of moisture.

Aqueous wastes from NC production originate from washing, boiling and dewatering. The neutral boil wastewater from the boiling tub house contains most of the NC fines lost during operations and processing. This and other wastewaters are currently collected in special pits where most of NC fines settle out and are periodically removed and returned to the process for reuse. The quantity of NC fines currently lost in the overflow is estimated at 1 metric ton (2200 lbs)/day/line, or about 0.072% of the NC output. In

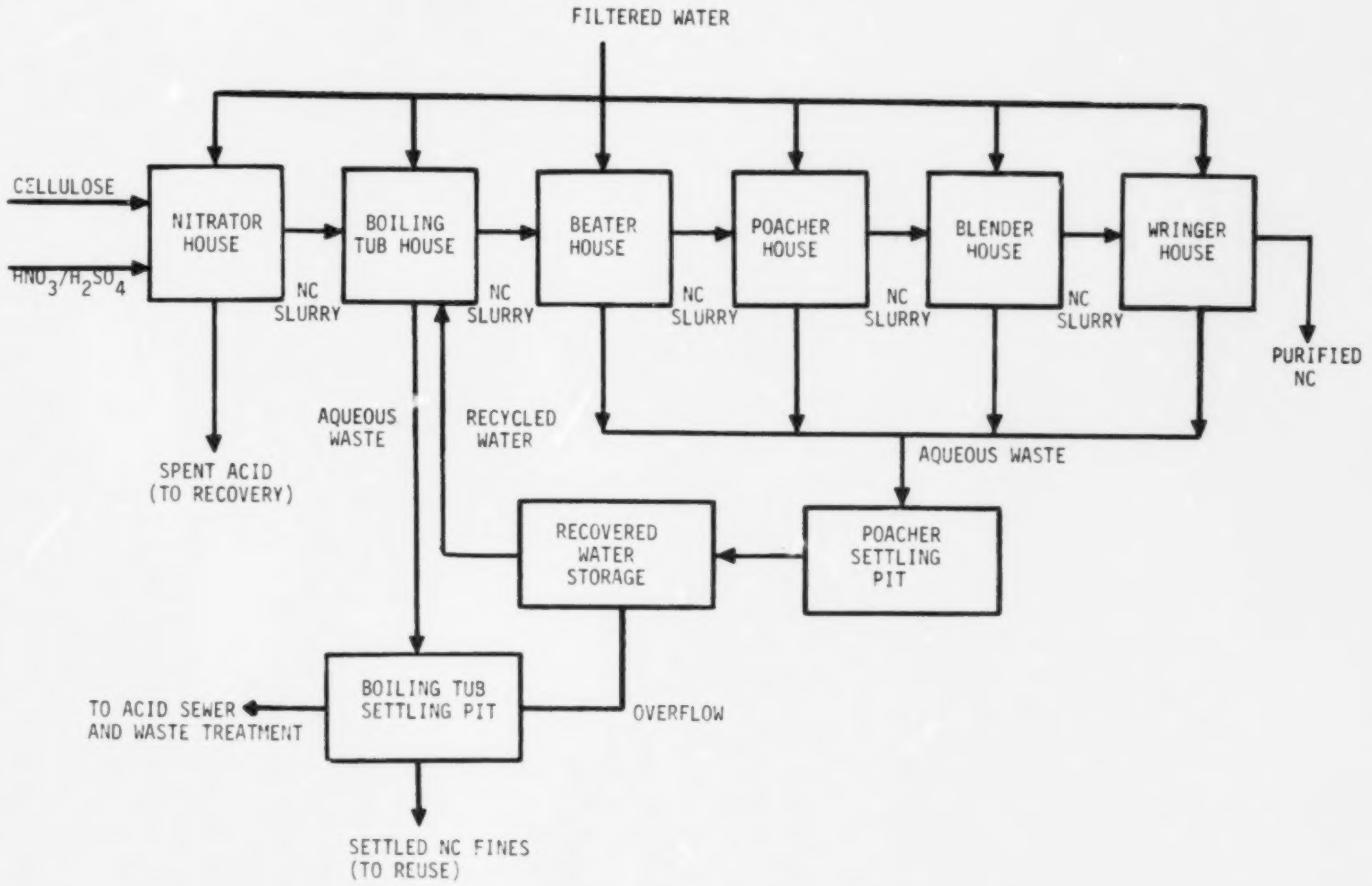
FILTERED WATER
CELLULOSE
HNO_3/H_2SO_4
NITRATOR HOUSE
BOILING TUB HOUSE
BEATER HOUSE
POACHER HOUSE
BLENDER HOUSE
WRINGER HOUSE
NC SLURRY
NC SLURRY
NC SLURRY
NC SLURRY
NC SLURRY
PURIFIED NC
SPENT ACID (TO RECOVERY)
AQUEOUS WASTE
RECYCLED WATER
AQUEOUS WASTE
RECOVERED WATER STORAGE
POACHER SETTLING PIT
BOILING TUB SETTLING PIT
TO ACID SEWER AND WASTE TREATMENT
OVERFLOW
SETTLED NC FINES (TO REUSE)

Figure 5-30. Nitrocellulose Production at Radford AAP

the future this loss of NC fines will be significantly reduced when the neutral boil wastewater is isolated and treated separately by centrifugation. Based on data for Radford AAP, for a production rate of 66,000 kg/day and with a considerable amount of water recirculation, the total volume of the final wastewater effluent from NC production is estimated at 9500 m^3 per day (2.5 million gallons per day). The major solid waste from the process is contaminated NC which is estimated at 1-2 percent of the NC production. Acid fumes are the major air pollutants from NC production.

Plant modernization program for Radford AAP calls for the replacement of the batch operation with a continuous NC production process. Table 5-23 presents mass balance data for the proposed continuous lines. The data are based on the production of 50 percent linters NC and the use of Delaval centrifuges for the removal of NC fines from wastewaters.

Nitroglycerin (NG) Production

Nitroglycerin is manufactured by a closely controlled reaction between glycerin and a mixture of nitric and sulfuric acids. The reactor is equipped with cooling coils through which a cold brine solution is circulated. Both batch and continuous (Biazzi) processes are in current use. One commercial nitroglycerin manufacturing plant uses a mixture of glycerin and ethylene glycol as the starting material; the product obtained in this plant is a mixture of nitroglycerin and ethylene glycol dinitrate.

Following nitration, the NG is separated from the spent acid by gravity separation and purified by washing with water and with a solution of sodium carbonate. Most facilities are equipped with settling pits and catch basins for the capture and return to process of most of the nitroglycerin particles entrained in the wastewaters. At Radford AAP, the spent acids are recovered and reused. Steam is used for denitrifying the spent acid at one commercial facility. At this facility, the effluent steam containing nitric acid is discharged directly to the atmosphere, and the sulfuric acid is stored in a lagoon for sale as a by-product. A block flow diagram for NG production is presented in Figure 5-31. Table 5-24 presents the material balance for NG production (based on operating conditions at Radford AAP).

Table 5-23. Mass Balance Data for Modernized Nitrocellulose Production (kg per kg of NC Produced)

Feedstocks		Products/losses	
Cellulose	0.61	Cellulose in NC	0.60
		Cellulose lost	0.01
HNO_3	1.67	HNO_3 recovered	0.76
		HNO_3 consumed	0.91
		HNO_3 lost in fumes and to wastewater	0.41
H_2SO_4	0.50	H_2SO_4 recovered	0.46
		H_2SO_4 lost to wastewater	0.04

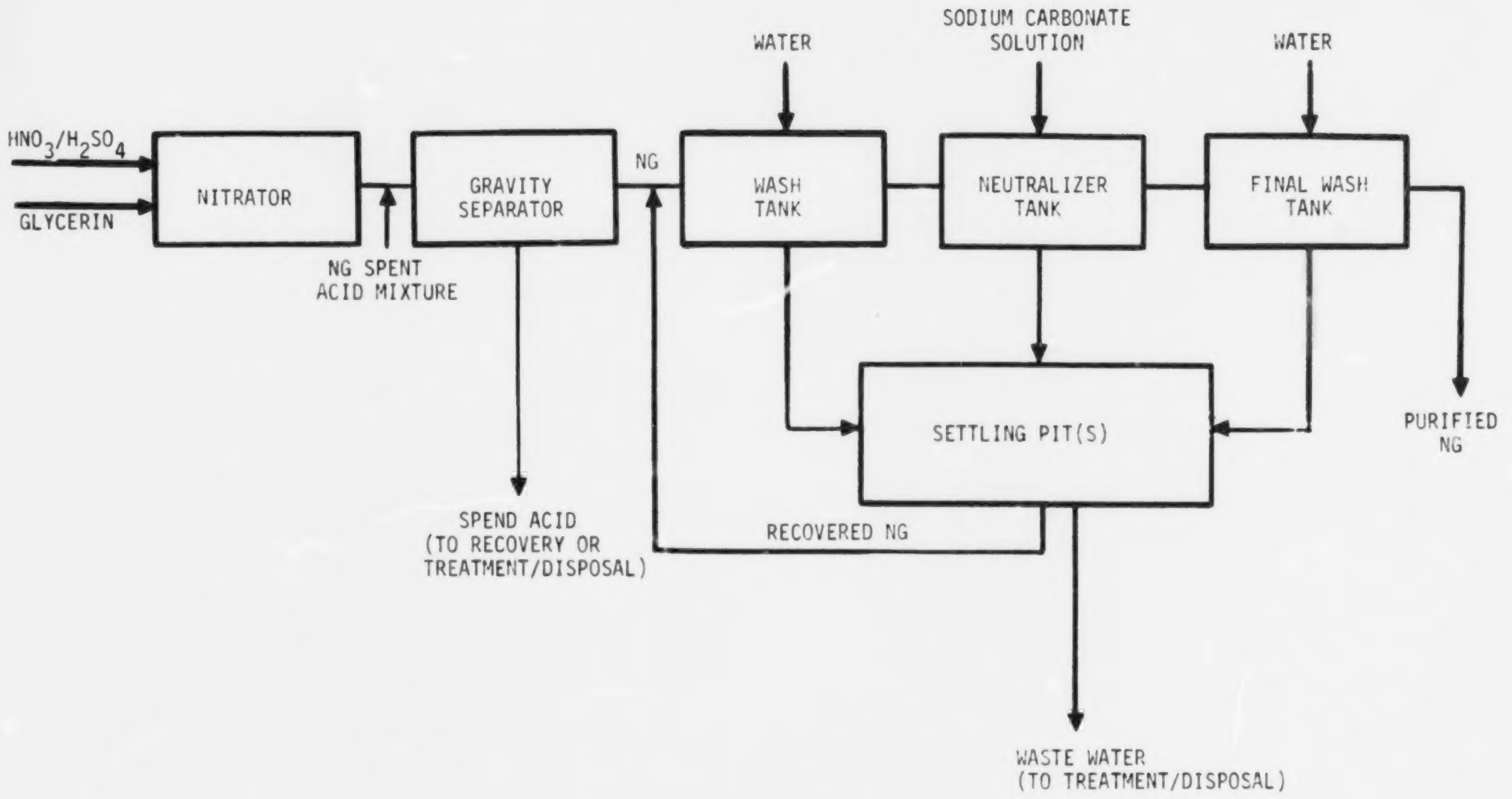
HNO3/H2SO4
GLYCERIN
NITRATOR
NG SPENT ACID MIXTURE
GRAVITY SEPARATOR
SPEND ACID (TO RECOVERY OR TREATMENT/DISPOSAL)
NG
WATER
WASH TANK
SODIUM CARBONATE SOLUTION
NEUTRALIZER TANK
WATER
FINAL WASH TANK
PURIFIED NG
SETTLING PIT(S)
RECOVERED NG
WASTE WATER (TO TREATMENT/DISPOSAL)

Figure 5-31. Schematic Flow Diagram for NG Production

Table 5-24. Mass Balance Data for Nitroglycerin (NG) Production (kg per kg NG Produced)

Mixed Spent Acid Input	2.13
Glycerin	0.42
Soda Ash	0.12
Spent Acid	0.15
Waste water	6.25
NG Lost to Waste water	0.006

HMX and RDX Production

HMX (cyclotetramethylenetetranitramine) and RDX (cyclotrimethylenetrinitramine) are used in the formulation of a variety of explosives compositions for ballistic use (see Section 5.4.1.2). A schematic flow diagram for the production of HMX and RDX at Holston Army Ammunition Plant is shown in Figure 5-32. Except for some differences in reaction conditions (e.g., reaction temperature), solution strength, and the handling method in the purification stage, the production steps for RDX and HMX are essentially identical. In fact, a small quantity of RDX is produced as an undesirable side-product in the production of HMX, and vice versa.

RDX/HMX manufacture is essentially a batch operation involving nitration of hexamine. The starting raw chemicals are nitric acid, ammonium nitrate, acetic acid, acetic anhydride, and hexamine. Following nitration, the crude production is vacuum filtered and washed until the residual acid content is less than 1 percent. Initial filtrates which contain about 60 percent acetic acid and 2-3 percent nitric acid are sent to an acid recovery facility and the secondary filtrates are combined and returned to the nitration building for reuse in slurrying the product. Washed explosives are reslurried with water and pumped to the finishing building. There RDX is recovered directly in dissolvers where solvent, either acetone or cyclohexanone, is added to effect dissolution prior to recrystallization. HMX is received in a tank where the solids settle out and the water is decanted to a filtration unit ("neutch"). HMX is then pumped to dissolvers where solvent is added for dissolution. The product is recrystallized from the solvent and the solvent is recovered for reuse. The objective of recrystallization is to remove residual acidity, to control particle size, and to improve product stability.

The spent acid from filtration of the crude RDX/HMX contains about 60 percent acetic acid, 2-3 percent nitric acid and some RDX/HMX. The spent acid is neutralized with sodium hydroxide and sent to the primary evaporators where about 80 percent of the acetic acid is recovered as a 60 percent solution. The residual "sludge" is then removed, diluted, heated and cooled to effect crystallization of RDX/HMX. To aid and promote recrystallization, a slurry of purified RDX/HMX is added to the solution during cooling. The crystallized product is then recovered in cyclone separators and sent to the process for

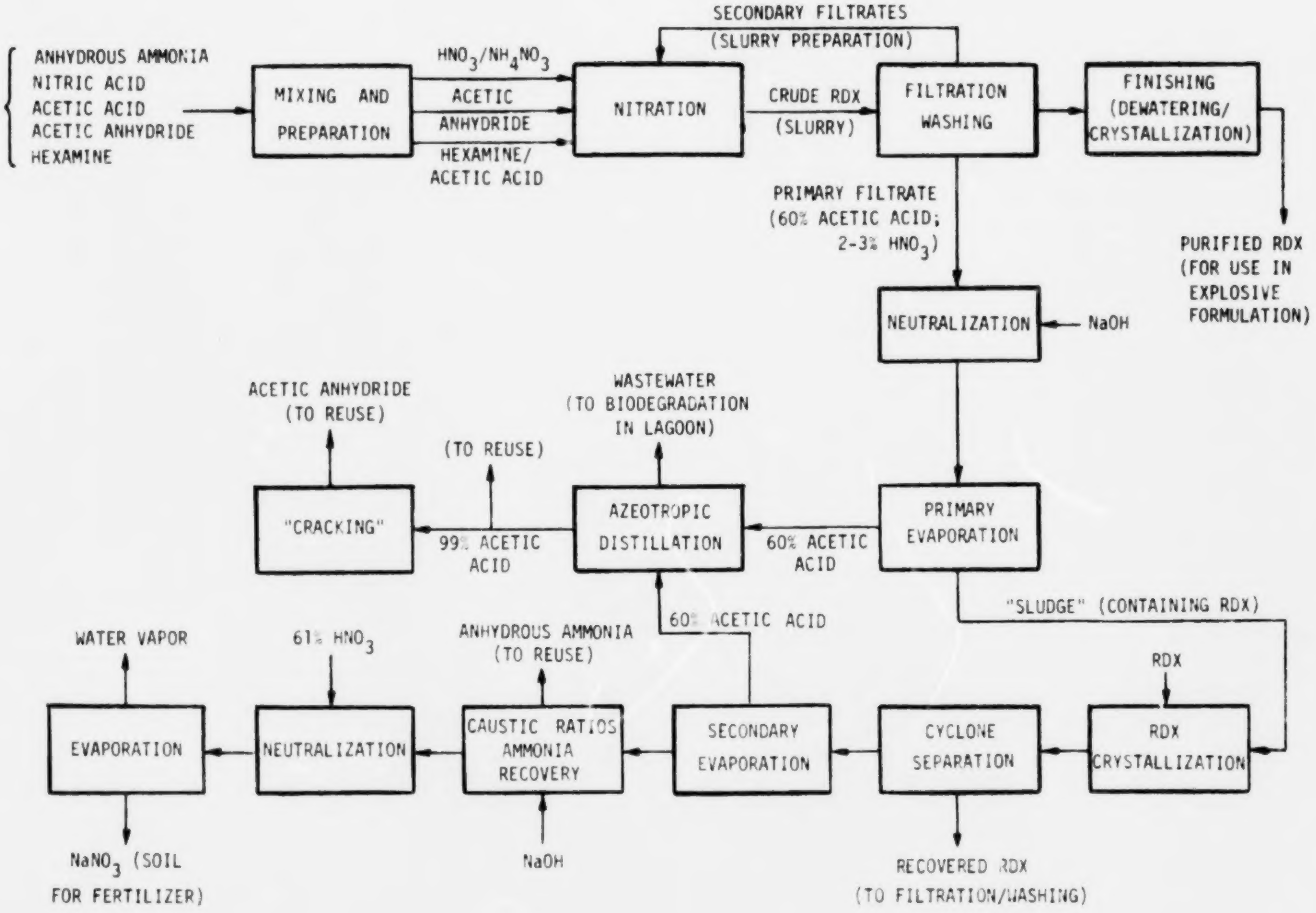
ANHYDROUS AMMONIA
NITRIC ACID
ACETIC ACID
ACETIC ANHYDRIDE
HEXAMINE
MIXING AND PREPARATION
HNO_3/NH_4NO_3
ACETIC ANHYDRIDE
HEXAMINE/ ACETIC ACID
NITRATION
SECONDARY FILTRATES (SLURRY PREPARATION)
CRUDE RDX (SLURRY)
FILTRATION WASHING
FINISHING (DEWATERING/ CRYSTALLIZATION)
PURIFIED RDX (FOR USE IN EXPLOSIVE FORMULATION)
PRIMARY FILTRATE (60% ACETIC ACID; 2-3% HNO_3)
NEUTRALIZATION
NaOH
PRIMARY EVAPORATION
60% ACETIC ACID
AZEOTROPIC DISTILLATION
WASTEWATER (TO BIODEGRADATION IN LAGOON)
99% ACETIC ACID
(TO REUSE)
"CRACKING"
ACETIC ANHYDRIDE (TO REUSE)
"SLUDGE" (CONTAINING RDX)
RDX
RDX CRYSTALLIZATION
CYCLONE SEPARATION
RECOVERED RDX (TO FILTRATION/WASHING)
SECONDARY EVAPORATION
60% ACETIC ACID
CAUSTIC RATIOS AMMONIA RECOVERY
ANHYDROUS AMMONIA (TO REUSE)
NaOH
NEUTRALIZATION
61% HNO_3
EVAPORATION
WATER VAPOR
$NaNO_3$ (SOIL FOR FERTILIZER)

Figure 5-32. Schematic Flow Diagram for RDX Production

reuse. A portion of the resulting liquid is recycled to the primary evaporators and the rest is sent to secondary evaporators for further recovery of acetic acid. The "sludge" from the secondary evaporator is treated with sodium hydroxide to decompose residual RDX/HMX and to recover ammonia for reuse. The final sludge from the causticizing operation is neutralized with 61 percent nitric acid and evaporated to recover sodium nitrate which can be sold as a fertilizer.

The acetic acid (60 percent) recovered in primary and secondary evaporators is concentrated to 99 percent strength by azeotropic distillation. The operation generates about 5,400 kg (12,000 lb)/month of a wastewater (at 40 percent operating capacity) containing methyl nitrate (10 percent), nitromethane, methyl acetate, propyl formate, propyl acetate and other esters and alcohols. At present, the wastewater is subject to biological degradation in a treatment lagoon. A portion of the concentrated (99 percent) product acetic acid is sent to process for reuse; the remaining quantities are used for the production of acetic anhydride.

5.4.1.2 Explosives Formulation

Production of propellants and explosive compositions, and "packing" the explosive products into munition items (LAP operations) are considered here as formulation operations. Wastes requiring treatment/disposal originate from spillage of ingredients and final products, materials not meeting specifications, and from general equipment clean-up. At Army ammunition plants, the production of propellants, explosive compositions, and munition items are versatile operations with the production facilities capable of producing a wide variety of products for different applications.

Propellants

Most of the propellants produced currently are of two basic types: solvent and solventless. Depending on the number of explosive ingredients, solvent-type propellants may be single-base, double-base, or triple-base. Typical compositions for a single-base, a double-base and a triple-base propellant are shown in Table 5-25. Solvent propellants are produced by mixing the ingredients in a suitable organic solvent (ethyl alcohol, acetone,

Table 5-25. Typical Composition of Propellants (Percent)

Major Ingredients	Single Base	Double Base	Triple Base
Nitrocellulose	84	67	48
Nitroglycerin	—	25	28
Nitroguanidine	—	—	22
Dinitrotoluene	10	—	—
Dibutyl phthalate	5	—	—
Diphenylamine	<1	—	—
Potassium sulfate	<1	—	—
Ethyl centralite (symmetrical diethyl diphenyl urea)	—	6	1.5
Barium nitrate	—	0.75	—
Potassium nitrate	—	0.70	—
Graphite	—	0.3	—
Cryolite	—	—	0.3

ether, etc.) to obtain the desired blend. The mixture then undergoes a series of operations for shaping into cylindrical blocks, extruding into strands and cutting to desired size. The operation is batch process and in general most of the solvent is recovered and reused. Production of solventless propellants ("rolled powder") is similar to that for solvent propellants except that no organic solvent is used in the mixing step. The operation is a batch process in which nitrocellulose, nitroglycerin and other ingredients are slurried in water, wrung to a wet cake, and dried to a paste. The paste is then rolled into sheets and wound into a "carpet roll" for extrusion into small rocket grains, or processed into "mortar increments".

Based on the operation at Radford AAP, the quantity of explosive wastes generated in the manufacturing of propellants is estimated to range from 4-10 percent of the finished product. In the production of double-base propellants, approximately 0.125 kg of ethyl alcohol and 0.1 kg of acetone are lost to the atmosphere per kg of propellant manufactured.

Explosive Compositions

Holston AAP (Kingsport, Tennessee) formulates a variety of explosive compositions for use by the military with minor use by the National Aeronautic and Space Administration. These explosive compositions have specified ballistic properties and contain RDX or HMX as their prime ingredient. The production operation involves addition of RDX (or HMX) to various explosives (e.g., TNT), and nonexplosive (e.g., wax) compounds to produce a plastic bonded material or a solidified end product. The make-up of a number of major military explosive compositions are presented in Table 5-26.

Based on the weekly Burning Ground record for May 20 to July 22, 1974,(56) and the 1973 production data,(18) the solid waste generated in the formulation of Composition B is estimated at 0.0005 kg of waste per kg of final product.

Dynamites

Although there are many different dynamite formulations, most commercial dynamites contain nitroglycerin and sodium and/or ammonium nitrate as their major ingredients. Many dynamites are formulated to the customer's specifications and some also contain a number of proprietary ingredients. The most common ingredients of dynamites are listed in Table 5-27. Typical composition for "straight" dynamite with "active" base (sodium nitrate) is presented in Table 5-28.

Dynamite formulation involves, first, mixing ammonium and/or sodium nitrate with various nonexplosive ingredients. Nitroglycerin is then added and the product is transported to a cartridge house for packaging into waxed cardboard boxes or plastic tubes for final shipment or storage in magazines.

Wastes from dynamite formulation originate from spills, off-spec products, and equipment clean-up. A waste generation factor of 0.3 percent of the production rate is estimated for the formulation of dynamite.(57)

Ammonium Nitrate-Fuel Oil Mixture (ANFO)

In 1973 ANFO compositions accounted for close to 70 percent of all commercial explosives used. ANFO is a mixture of ammonium nitrate (about 94 percent) and fuel oil (about 6 percent) to which may be added a variety of minor ingredients such as aluminum powder, ferrophosphate, coal, calcium silicate, Atticote, and mineral oils. Some ANFO compositions may contain up to 5 percent aluminum powder. ANFO formulation may be a batch or a continuous

Table 5-26. Makeup of Major Explosive Compositions

Explosive Composition	Principal Ingredients
Composition A-3	RDX (91%), Wax (9%)
Composition B	RDX (60%), TNT (39%), Wax (1%)
Composition C-4	RDX (91%), Polyisobutylene (2.1%), Motor oil (1.6%), di(2-ethylhexyl) sebacate (5.3%)
Cyclotol 70/30	RDX (70%), TNT (30%)
Octol 70/30	HMX (70%), TNT (30%)
Octol 75/25	HMX (75%), TNT (25%)

Table 5-27. Common Ingredients of Dynamites

Nitroglycerin
Ammonium Nitrate
Sodium Nitrate
Sodium Chloride
Calcium Carbonate
Sulfur
Nitrocellulose
Phenolic Resin Beads
Bagasse
Sawdust and Wood Pulp
Coal
Corn Meal and Corn Starch
Trace Inorganic Salts
Grain and Seed Hulls and Flours

Table 5-28. Typical Composition of "Straight" Dynamite with "Active" Base

Component	Percent, Weight
Nitroglycerin	40
Sodium Nitrate	44 - 45
Wood Meal	12 - 15
Calcium Carbonate	1 - 3

blending operation, with waste originating mainly from spillage and equipment clean-up. Solid waste generated in the formulation of blasting agents (ANFO and water gels and slurries) is estimated as approximately 0.1 percent of the production. Large, centrally located ANFO formulators market their products in bulk or in bags or cylinders. Occasionally, the fuel oil is "dyed" prior to mixing with the nitrate salt to identify specific formulations. Many of the small ANFO formulators are located near mine use areas. These on-site facilities receive ammonium nitrate and fuel oil in bulk quantities, blend the ingredients to customer specifications and transport the finished ANFO by trucks to the mine.

5.4.1.3 LAP Operations

Most of the Army ammunition plants which conduct LAP operations do not have on-site explosive manufacturing capabilities. In these plants, the explosives are shipped in from other AAP's. Most LAP operations involve melting of the explosives and loading the molten product into metal shells of projectiles. The loaded projectiles are cooled, transferred to an assembly area for the installation of end items, inspected, and the acceptable rounds are packed for shipment and/or storage. The operational flow chart for a loading line at Louisiana AAP (Shreveport, La.) is shown in Figure 5-33.

Solid wastes generated in LAP operations include contaminated and rejected explosives, floor sweepings containing spilled explosives, and explosive-containing sludges from wastewater collection sumps. Wastewaters originate

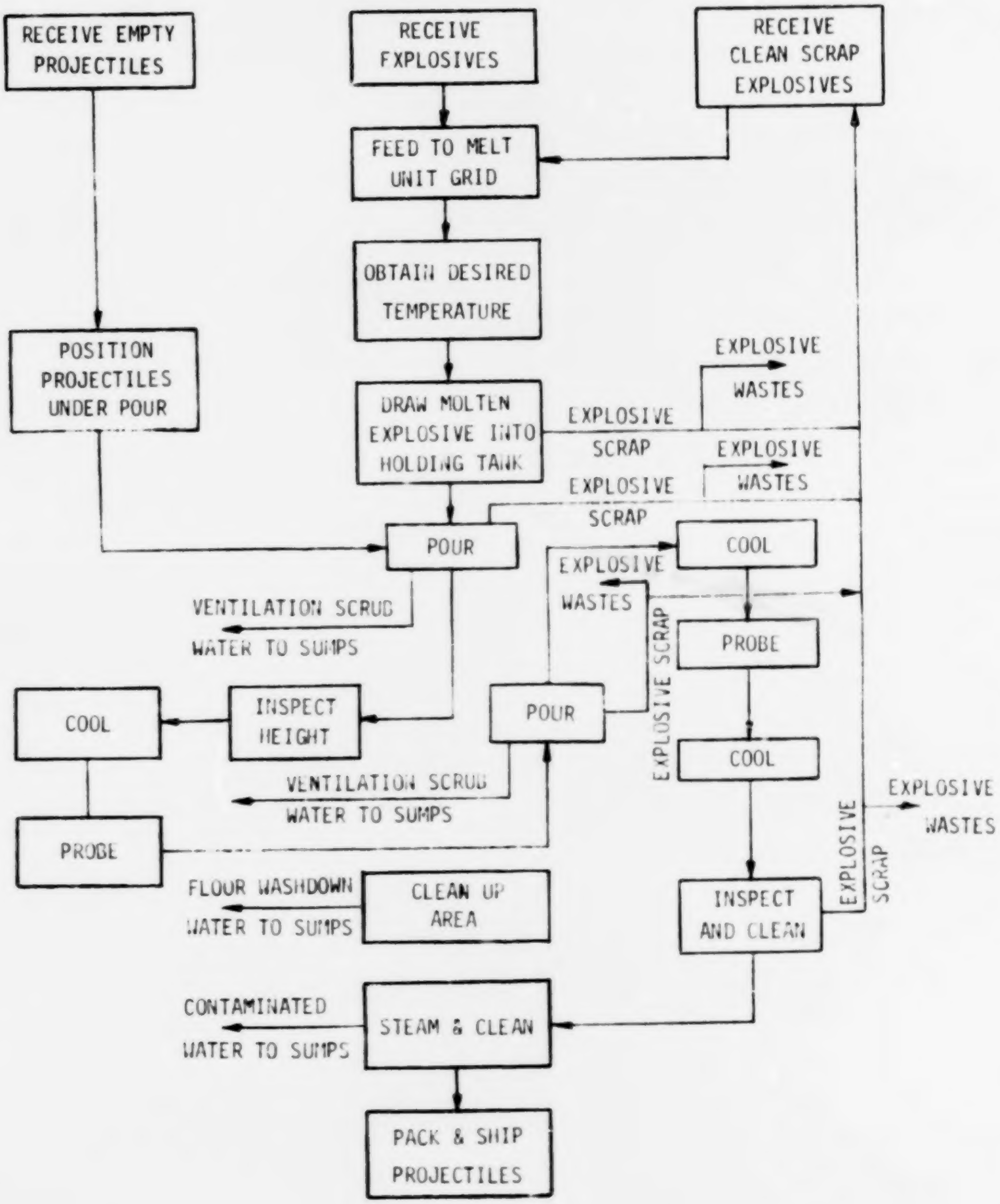
RECEIVE EMPTY PROJECTILES
RECEIVE EXPLOSIVES
RECEIVE CLEAN SCRAP EXPLOSIVES
FEED TO MELT UNIT GRID
OBTAIN DESIRED TEMPERATURE
POSITION PROJECTILES UNDER POUR
DRAW MOLTEN EXPLOSIVE INTO HOLDING TANK
EXPLOSIVE WASTES
EXPLOSIVE SCRAP
EXPLOSIVE WASTES
EXPLOSIVE SCRAP
POUR
COOL
EXPLOSIVE WASTES
VENTILATION SCRUB WATER TO SUMPS
PROBE
EXPLOSIVE SCRAP
COOL
INSPECT HEIGHT
POUR
COOL
VENTILATION SCRUB WATER TO SUMPS
EXPLOSIVE WASTES
PROBE
EXPLOSIVE SCRAP
FLOUR WASHDOWN WATER TO SUMPS
CLEAN UP AREA
INSPECT AND CLEAN
CONTAMINATED WATER TO SUMPS
STEAM & CLEAN
PACK & SHIP PROJECTILES

Figure 5-33. Operational Flow Chart for a Projectile Loading Line

mainly from "steam-out" and wash-out of rejected bombs and from washing of equipment and floors. Since TNT is usually an ingredient of the explosives used, the wastewaters from LAP operation are characteristically pinkish in color and are referred to as "pink water". Carbon adsorption is an effective method for the removal of nitrobodies from pink water; disposal of spent carbon is a problem in solid waste management. Very little air pollution is associated with the LAP operation.

There are significant variations in waste generation factors for different LAP operations, depending on the specific items loaded, method and equipment used for loading, and extent of in-plant waste management and housekeeping. Two typical waste generation factors are 0.0132 and 0.0416 kg waste explosives per kg of explosives in product ordnance items. Material balance for two LAP operations at Joliet Army ammunition plant is shown in Table 5-29. Modernization programs, which are planned for this plant and for other AAP's, are expected to result in significant improvements in the operational efficiency of the LAP lines and, hence, in a reduction in the quantity of waste generated.

5.4.2 Annual Process Stream Discharge to Land Disposal

Table 5-30 contains a summary of the estimated quantities of hazardous wastes generated in the production of commercial explosives. The following assumptions were used in arriving at these estimates: (1) The quantity of explosives produced in each state or EPA region is equal to the quantity of explosives sold for consumption in that state or region (Table 4-10). (2) Waste generation factors for fixed high explosives and blasting agents are 0.003 and 0.001 (weight per weight of product), respectively.(57) These assumptions and estimated production increases (over the 1973 level) of 10 percent by 1977 and 21.6 percent by 1983 were used to estimate waste quantities for 1977 and 1983. The production increases reflect the increases in the GNP projected for 1977 and 1983.(51)

The "wet-basis" quantities of process waste sent to land disposal by private explosives industry were estimated assuming that the ratio between wet-basis wastes and dry-weight basis wastes discharged to the land, is the same as that for the organic chemicals industry, (i.e., by using a factor of 3.17 - see Section 5.2.2). On this basis the private

Table 5-29. Material Balance for Two LAP Operations at Joliet AAP

Item No.	Process/Operation	Process Input	Process Output	Losses
1	LAP Melt loading of 105mm Cartridge	Composition B 21,521 kg	10,000 loaded projectiles Composition B in loaded projectiles 46,580.002 lb	Composition B Scrap to Burning Grounds 281.4 kg Composition B Washings to the Carbon Columns and then to Burning Grounds 3.64 kg
2	LAP 40mm Cartridges, M406	Composition B 3,502 kg Propellant Powder 3.6 kg Booster Pellets 10,017 Units Projectiles 10,044 Units	10,000 acceptable rounds	Composition B Losses 107.4 kg Composition B to Scrap and then to Burning Grounds 36.3 kg Composition B to Carbon Column and then to Burning Grounds 0.45 kg Booster Units 17 Units Propellant Powder 0.19 kg Rejected Projectiles 44 Units Composition B in rejected Projectiles 1.36 kg

Table 5-30. Explosive Wastes[1] Discharged to Land Disposal, Metric Tons for CY 1973 for the Private Explosives Industry (SIC 28921) (With Comparative Totals for CY 1977 and CY 1983)

EPA Region	State	Fixed HE	Blasting Agents	Total Wastes	Total - 1977	Total - 1983
4	Alabama	18	81	99	109	120
10	Alaska	6	0.35	6	6	8
9	Arizona	8	83	91	100	110
6	Arkansas	3	7	10	11	12
9	California	7	28	35	38	42
8	Colorado	12	6	18	19	22
1	Connecticut	9	6	15	16	18
3	Delaware	0.17	0.005	0.18	0.2	0.2
3	District of Columbia					
4	Florida	34	10	44	48	53
4	Georgia	8	12	20	22	24
9	Hawaii	0.63	1	2	2	2
10	Idaho	4	4	8	9	10
5	Illinois	18	45	63	70	77
5	Indiana	3	54	57	64	70
7	Iowa	12	10	22	24	27
7	Kansas	2	[illegible]	[illegible]	6	[illegible]
4	Kentucky	38	144	182	196	219
6	Louisiana	2	2	4	4	5
1	Maine	2	1	3	3	4
3	Maryland	6	5	11	12	13
1	Massachusetts	5	2	7	7	8
5	Michigan	5	24	29	32	35
5	Minnesota	3	51	54	59	65
4	Mississippi	3	0.006	3	3	3
7	Missouri	18	26	44	48	54
8	Montana	4	1	5	6	7
7	Nebraska	1.87	0.69	[illegible]	[illegible]	2
9	Nevada	0.58	12	13	14	15
1	New Hampshire	2	0.31	2	3	3
2	New Jersey	4	2	6	[illegible]	[illegible]
6	New Mexico	[illegible]	27	[illegible]	36	40
2	New York	11	8	19	21	23
4	North Carolina	9	10	19	20	22
8	North Dakota		0.37	0.37	0.4	0.4
5	Ohio	13	68	81	89	98
6	Oklahoma	3	15	18	20	22
10	Oregon	7	4	11	12	13
3	Pennsylvania	39	117	156	171	189
2	Puerto Rico					
1	Rhode Island	0.30	0.28	0.58	0.6	0.7
4	South Carolina	2	1	3	4	4
8	South Dakota	0.19	0.84	1	1	1
4	Tennessee	19	35	54	59	65
6	Texas	9	18	27	29	32
8	Utah	3	17	20	22	24
1	Vermont	2	0.18	2	2	3
3	Virginia	22	38	60	66	73
10	Washington	6	5	11	13	14
3	West Virginia	24	62	86	95	105
5	Wisconsin	4	8	12	13	15
8	Wyoming	1	5	6	6	7
NATIONAL TOTALS		417[2]	1111[2]	1528[2]	1681[2]	1858[2]

REGIONAL TOTALS					
1	20	11	31	34	37
2	15	10	25	27	29
3	91	222	313	344	380
4	131	291	422	463	570
5	46	250	296	327	362
6	22	69	91	100	111
7	33	40	73	80	90
8	20	30	50	54	66
9	16	124	140	154	169
10	23	13	36	40	45

[1] Estimated, water-free basis, using the procedures given in Section 5.4.2 and Appendix A "Methodology Details." The data for the calculations was obtained from References 7, 16, 51 and 57.

[2] Includes undistributed production (that portion of the national total reported for which no state or region allocation was possible).

explosives industry was estimated to have discharged approximately 5,000 metric tons (wet-basis) of process waste to land in 1973. The figures projected for 1977 and 1983 were 5,500 metric tons and 6,000 metric tons (wet-basis).

Estimates of the 1973 waste quantities for the manufacture of military explosives are shown in Table 5-31. The data are based on:(1) a 1974 Resource Recovery Information survey by U. S. Army Material Command Installation and Service Agency,(58) (2) visits to several Army ammunition plants and arsenals, and (3) the TRW data file on operations at various AAP's.

Historically, the production at ammunition plants has varied significantly in response to the fluctuating demand for munitions. As an example, Joliet AAP was first placed in operation during World War II. In August 1945 all production of explosives was halted, the sulfuric acid and ammonium nitrate plants were leased out, and the remaining production facilities were put in lay-away status. In August 1965, reactivation of the explosives manufacturing area was initiated and production of chemicals and explosives commenced in April 1966. In the LAP area, the operation was also halted in August 1945. The facility, however, was reactivated in 1951 for the Korean action. Subsequent curtailment of the operation was started in 1956 although the AAP was in a high state of readiness until it was reactivated in October 1966. Since early 1969 there has been a general gradual decrease in the production rate with current (1974) production level close to the minimum for the period.

Because of the extreme unpredictability of future political and military conditions, it is exceedingly difficult, if not impossible, to estimate munition production for 1977 or 1983. This was indeed the response received from plant managers and Army personnel during site visits and interviews. The prediction of the quantity of wastes requiring final disposal is even more difficult in the light of planned pollution control and modernization programs. These programs, which will result in significant reductions in pollution generation, are at various stages of design, construction, planning, and funding consideration. Although tentative target dates have been established for most of the projects, in the past the target dates have not always been met and some of the programs have been cancelled or modified. Because of these uncertainties which influence both production and waste generation, 1977 and 1983 waste production were assumed to remain at the 1973 level, which reflects peacetime operations.

Table 5-31. Explosive and Explosive Contaminated Wastes Discharged to Land Disposal, Metric Tons for CY 1973 – GOCO Plants, Explosive Industry (SIC 28922)*

EPA Region	State	Explosive Wastes: Open Burned	Explosive Wastes: Sold	Explosive Contaminated Inert Wastes: Open Burned	Explosive Contaminated Inert Wastes: Land Filled	Other Hazardous Wastes: Sold	Other Hazardous Wastes: Open Burned	Other Hazardous Wastes: Land Filled
4	Alabama							
10	Alaska							
9	Arizona							
6	Arkansas							
9	California	260		27				
8	Colorado							
1	Connecticut							
3	Delaware							
3	District of Columbia							
4	Florida							
4	Georgia							
9	Hawaii							
10	Idaho							
5	Illinois	163	78	900				
5	Indiana	119		49	535			
7	Iowa	204		71				
7	Kansas	76	58	762				
4	Kentucky							
6	Louisiana	454		692				
1	Maine							
3	Maryland							
1	Massachusetts							
5	Michigan							
5	Minnesota							
4	Mississippi							
7	Missouri				253		80	
8	Montana							
7	Nebraska	147		890		19	0	0
9	Nevada							
1	New Hampshire							
2	New Jersey							
6	New Mexico	69		24				
2	New York							
4	North Carolina							
8	North Dakota							
5	Ohio	1						
6	Oklahoma							
10	Oregon							
3	Pennsylvania							
2	Puerto Rico							
1	Rhode Island							
4	South Carolina							
8	South Dakota							
4	Tennessee	335		7776	218		9	136
6	Texas	472		54				
8	Utah	739		86				
1	Vermont							
3	Virginia	1078		2370				
10	Washington							
3	West Virginia							
5	Wisconsin	646						
8	Wyoming							
NATIONAL TOTALS		4763	136	13701	1006	19	89	136

REGION TOTALS							
1							
2							
3	1078		2370				
4	335		7776	218		9	136
5	929	78	949	535			
6	995		770				
7	427	58	1723	253	19	80	-
8	739		86				
9	260		27				
10							

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* Covers active AAP's, AEC facilities and two commercial plants, one in Utah and one in California, manufacturing propellants under Air Force contracts. Quantities were estimated on a water-free basis, in accordance with the procedures given in Appendix 2. The data for the calculations were obtained from the U.S. Army and Army Ammunition Plant sources listed in Table 8-1 and References 17, 18, 56, 58 and 59.

The great majority of explosives wastes discharged by the GOCO plants (in excess of 93 percent) were treated/disposed of on-site because of their highly dangerous character. These wastes were either dry or of very low moisture content (less than 10 percent). The small quantities of GOCO plant process wastes which were sold or land-filled were also low in water content. The "wet-basis" national total estimated for GOCO plant process waste streams sent to land in 1973 was the same, therefore, as the dry weight basis estimate, 19,850 metric tons.

6. TREATMENT AND DISPOSAL TECHNOLOGY

6.1 GENERAL

The technologies used for treatment and disposal of the land-destined hazardous waste streams from the explosives industries are so markedly different from those common to the organic chemicals and pesticides industries that the results of this study are reported under two separate headings. The organic chemicals and pesticides industries, which differ only slightly in treatment and disposal technology, are covered in Section 6.2. The explosives industries' techniques, which historically stem from the concern of the ordnance industry with plant equipment and plant personnel safety rather than environmental impact, are discussed in Section 6.3.

Three treatment and disposal technology levels are identified in this study. Level I technology represents the practice currently employed by typical facilities — broad, average, present treatment and disposal practice. Level II is the best technology currently in commercial use in at least one location for the same or a similar application — "best" here referring to the adequacy of the process from an environmental and health standpoint. Level III is the technology necessary to provide adequate environmental protection, and may include pilot or bench scale processes. Level I, II, and III technology may be identical in those cases where the broad, average, present treatment is both the best technology currently in use and is environmentally adequate.

Company and Government agency-supplied information, used in this study, which covered treatment and disposal technologies employed at 52 major plant sites, was obtained by visits to 34 plants and/or company headquarters, and to 4 off-site contractor disposal sites, and through other direct contacts. For the organic chemicals and pesticides industries, the data embraced the technology for disposal of just under 200 hazardous waste streams. Data were received from the U. S. Army Armament Command on land disposal activities at all of the Army ammunition plants, in addition to the personal observations made at three of the four active basic high explosives manufacturing plant sites and the information furnished on treatment and disposal development projects.

Fifteen land-destined hazardous waste streams (one each from 15 of the 26 hypothetical typical plants chosen to represent the organic chemicals and technical organic pesticides industries) were selected to give composite pictures of characteristic treatment and disposal technologies employed in the two industries. The number of hazardous waste streams, for which disposal technologies could be subjected to detailed analysis in this study, had time and cost limitations in addition to the limitations imposed by data availability; the 15 hazardous waste streams were, therefore, chosen on the basis of product significance and hazardous waste significance. Production in 1973 of the ten organic chemicals selected constituted just over 7 percent of the total production of the organic chemicals industry. The discharge of the ten process waste streams investigated in depth from plants manufacturing the ten organic chemicals totaled close to 16 percent of the aggregate dry weight of all hazardous wastes discharged to land in 1973 by the organic chemicals industry. The production total (excluding pesticide formulations and preparations) in 1973 for the five technical organic pesticides selected was just under 26 percent of the national total production for all technical organic pesticides. The dry weight of the five technical pesticide waste streams studied (from all plants producing these five technical pesticides) constituted approximately 21 percent of the dry weight of all hazardous wastes discharged to land in 1973 by this industry.

The technology used in 1973 for disposal of the three major types of process waste streams sent to land by the plants of the military explosives industry is described in Section 6.3.1. The limited data available on the waste treatment and disposal techniques used in 1973 by the private explosives industry are summarized in Section 6.3.2.

6.2 ORGANIC CHEMICALS AND PESTICIDES INDUSTRIES

Summaries of the specific information on land-destined hazardous waste treatment and disposal practices in the organic chemicals and pesticides industries, collected from companies cooperating in this study, are presented in Tables 6-1, 6-2 and 6-3. Tables 6-1 and 6-3 contain data on waste treatment and disposal methods used in the organic chemicals and pesticides industries, respectively. Table 6-2 presents data on treatment/disposal technology distribution for selected organic chemicals plant sites.

Table 6-1. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Liquid tars, still bottoms and process residues	Incineration, uncontrolled, energy recovery	17,800
Liquid tars and oils (still bottoms)	Landfill	300
Liquid tars (still bottoms)	Incineration, controlled	300
Waste water, condensate	Incineration, controlled	7,600
Liquid tars	Landfill	50
Liquid tars and oils	Landfill	140
Liquid, tars and oils	Landfill	90
Liquid, tars and oils	Landfill	50
Liquid, oils (distillation residue)	Landfill	50
Semi-solid phenolic wastes	Landfill, drummed	70
Solid, spent activated carbon	Recovery	Not Available
Liquid process wastes (phenols, alcohols, etc.)	Incineration, controlled	1,600
Liquid, dispersed in water organics[1] with metal catalyst	Incinerator controlled[2] Landfill, drummed	21,800
Liquid, mixed process waste[3] slurry in water	Deep well	254,000[4]
Liquid tars, reactor byproduct	Incinerator, uncontrolled	1,800
Liquid tars, byproduct	Incinerator, uncontrolled	500
Liquid organic wastes	Contractor landfill	200
Solid organic wastes and trash	Contractor landfill	200
Fluid residues	Incineration, uncontrolled, energy recovery	14,100
Fluid residues, miscellaneous		1,600
Sludge, filter residues	Landfill	360
Solid reactor residues	Landfill	160

Table 6-1. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Solid residual pitch	Landfill	830
Solid, spent metal oxide catalyst	Recovery and byproduct sales	60
Fluid, reactor residue	Incineration, uncontrolled, energy recovery	170
Fluid, reactor recycle		60
Fluid, still heads		130
Solid, spent metal catalyst	Recovery and recycle	14
Liquid (thick), reactor residue	Incineration, uncontrolled, energy recovery	680
Semi-solid residue	Landfill	16
Liquid, wash water waste	Activated sludge and lagoon[5]	1,000
Liquid, activated sludge from wash water waste	Incineration, controlled	90
Liquid, activated sludge, tar	Incinerator, controlled	4
Liquid, activated sludge	Incineration, controlled	36
Solids, filter residues	Incineration, controlled	70
Liquid reaction waste	Deep well injection	22,700
Liquid purification waste	Deep well injection	11
Liquid activated sludge from water-phase wastes	Incineration, controlled	5
Liquid still bottoms	Incineration, controlled	800
Liquid still bottoms	Incineration, controlled	800
Liquid, contaminated steam condensate	Deep well injection	90
Liquid, contaminated wash water	Deep well injection	30
Liquid, activated sludge from aqueous chloroaromatic wastes	Incineration, controlled	20
Liquid, activated sludge from aqueous chloroaromatic wastes	Incineration, controlled	80

Table 6-1. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Liquid still heavy ends	Incineration, controlled	500
Liquid, phenolic contaminated wash water	Activated sludge and lagoon	90
Liquid, activated sludge from wash water waste	Incineration, controlled	3
Liquid still bottoms	Incineration, controlled	70
Liquid, reprocessing tars	Incineration, controlled	200
Liquid, neutralization products	Deep well injection	6,000
Liquid, scrubber waste	Incineration, controlled (salt ash to industrial outfall)	400
Semi-solid, filter cake	Landfill	280
Liquid, still bottoms	Incineration, controlled (salt ash to industrial outfall)	1,100
Liquid, wash water	Activated sludge and lagoon	600
Liquid, activated sludge from wash water waste	Incineration, controlled	100
Liquid, contaminated condensate	Activated sludge and lagoon	20
Liquid, activated sludge from contaminated condensate	Incineration, controlled	4
Semi-solid, filter cake	Landfill	500
Liquid, wash-down wastes	Activated sludge and lagoon	100
Liquid, activated sludge from wash-down wastes	Incineration, controlled	20
Solid, spent ion exchange resin	Landfill	1
Solid, spent charcoal	Thermal regeneration (recovery)	50
Solid, wastes/residues	Incineration, uncontrolled	Not Available

Table 6-1. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual Quantity, metric tons/yr
Liquid, activated sludge from wastewater	Evaporation (spread on farm land)	Not Available
Liquid, neutralized Al salt solution	Contractor deep well, landfill and incineration	Not Available
Liquid wastes, toxic	Contractor disposal	Not Available
Liquid, oil sludge from waste water	Contractor disposal	Not Available
Solid, catalyst residue, Ni compounds	Recovery (Ni – 100%)	3
Solid, catalyst residue, Cr compounds	Recovery (Cr – 100%)	<1
Solid, catalyst residue, SiC compounds	Recovery	20
Liquid, distillation residue	Incineration, uncontrolled energy recovery	2,700
Solid, catalyst residue, Ni compounds	Recovery (Ni – 100%)	3
Solid, catalyst residue, Cr compounds	Recovery (Cr – 100%)	<1
Solid, catalyst residue, SiC compounds	Recovery	20
Fluid, aromatic residues	Incineration, uncontrolled energy recovery	260
Solid, spent catalyst, Sb salt	Landfill (encapsulated)	20
Solid, spent catalyst, Cu and oxides	Recovery (Cu – 100%)	3
Solid, spent catalyst (mol-sieve)	Landfill	5
Liquid, viscous	Incineration, uncontrolled energy recovery	8,200
Solid, spent catalyst, Ni compounds	Recovery (Ni – 100%)	20
Solid, spent catalyst, Cr compounds	Recovery (Cr – 100%)	<1

Table 6-1. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites (Continued)

Individual Hazardous Waste Stream	Disposal Process	Actual quantity, metric tons/yr
Solid, spent catalyst, SiC compounds	Recovery	20
Solid, spent catalyst, Co compounds	Incineration, uncontrolled, energy recovery	3
Solid, waste Na metal	Landfill	1
Fluid, organic residue	Incineration, uncontrolled energy recovery	300
Fluid, organic cyclic gums		9,000
Liquid, dryer waste, Ca salts	Deep well injection	14
Liquid, dryer waste, Ca salts	Deep well injection	5
Liquid, activated sludge	Incineration, controlled	230
Solid, filter wastes	Incinerator[6]	4
Liquid, vent scrubber wastes	Activated sludge and lagoon[7]	6,500
Liquid, tar dump	Activated sludge and lagoon[7]	45
Liquid, organics/acid	Activated sludge and lagoon[7]	2,300
Liquid, residues	Activated sludge and lagoon[7]	90
Semi-solid, chlorinated hydrocarbon heavies	Deep well injection	13,600
Semi-solid, lead compound sludge	Recovery furnace	9,100
Fluid, reactor byproduct	Incineration, controlled, energy recovery	1,600
Solid, copper compound residues	Recovery	3
Solid, Cr compound residues	Recovery	1

Table 6-1. Hazardous Waste Treatment/Disposal Methods at Selected Organic Chemical Plant Sites (Continued)

Composite Hazardous Waste Streams[8]		Disposal Process	Actual Quantity, metric tons/yr
4	Liquid hazardous waste streams	Recovery	2,350
5	Liquid hazardous waste streams	Incineration, controlled	3,860
10	Liquid hazardous waste streams	Incineration, uncontrolled	10,000
14	Liquid hazardous waste streams	Landfill	1,100[9]
23	Solid hazardous waste streams	Landfill	5,800[9]
4	Liquid or solid hazardous waste streams	Lagooned	Not Available
5	Liquid or solid hazardous waste streams	Contractor incineration	2,100
5	Liquid or solid hazardous waste streams	Contractor landfill	4,700

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1. 90% organics.
2. Metal recovered from incinerator ash.
3. About 0.5% organics in water.
4. Highly dangerous compound — 700 metric tons/year.
   Moderately dangerous compound — 600 metric tons/year.
5. Salts to outfall.
6. Soluble salts to industrial outfall, silicates to landfill.
7. Salts to industrial outfall.
8. Data composited to protect proprietary information.
9. Includes 800 metric tons stored hazardous wastes.

Table 6-2. Hazardous Waste Treatment/Disposal Technology Distribution — Selected Organic Chemical Plant Sites

Treatment and Disposal Location/Process	Number of Hazardous Waste Streams	% of Total Number of Hazardous Waste Streams	Annual Volume Actual Tons*	Percent of Total Annual Actual Tons	Annual Volume Estimated Dry Tons*	Percent of Total Annual "Dry" Tons
On-Site						
Landfill	55	31.6	20,723	4.7	20,723	14.8
Incineration	(58)	(33.3)	(97,759)	(21.9)	(97,759)	(69.7)
Controlled	31	17.8	30,411	6.8	30,411	21.7
Uncontrolled	27	15.5	67,348	15.1	67,348	48.0
Deep Well Injection	10	5.7	282,889	63.6	2,829	2.0
Biological Treatment/Lagoon	13	7.5	24,325	5.5	243	0.2
Recovery	21	12.1	11,670	2.6	11,670	8.3
Landfarm	1	0.6	NA**	NA	NA	NA
Contractor						
Landfill	9	5.2	5,100	1.1	5,100	3.6
Incineration	7	4.0	2,100	0.5	2,100	1.5
TOTAL	174		444,566		140,424	

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*metric tons

** NA indicates Not Available

Table 6-3. Hazardous Waste Treatment/Disposal Methods at Selected Pesticides Industries Plant Sites

Product		Individual Hazardous Waste Stream	Treatment/Disposal Methods
Technical Pesticides	Preparations Formulations		
X		Combined naphthol residues	Incineration, uncontrolled*
X		Spent catalyst (Ni, Cr, SiC)	Metal and SiC recovery.
X		Waste sodium metal	Controlled landfill
X		Dilute aqueous wastes	Evaporation ponds
X		Liquid wastes ("Autothermal")**	Incineration, controlled
	X	Dilute aqueous wastes	Evaporation ponds.
	X	Liquid wastes**	Incineration, controlled.
	X	Solid wastes (containers, bags, etc)	Classified, state-approved contractor landfill site.
X		Dilute acid solution, contaminated with phenols	Discharge to large bog (a biological waste water treatment has been constructed and will be used).
X		Spent carbon from acid purification	Open pile storage.
X		Methyl chloride Organic wastes Still bottoms	Incineration-ash to municipal solid waste.
X			
X			
X		Brine, contaminated with low concentration of pesticides, intermediates and solvent.	Deep well injection (1067 m. zone).
X		Sulfur byproduct from intermediate.	On-site landfill.
X		H_2S byproduct gas.	Incineration, uncontrolled.
X		HCl byproduct from intermediate.	Recovery and merchant sales.
	X	Dust from collectors and bag houses.	Contractor-operated state-licensed landfill.
X		Dryer dump.	Deep well injection.
X		Waste brine.	Deep well injection.
X		Contaminated condensate.	Biological treatment/polishing lagoon.
X		Solid filter cake residues	Incineration, controlled.
X		Acidic reactor wastes	Deep well injection.
X		Neutralization products (intermediate)	Deep well injection.
X		Scrubber bleed (intermediate)	Incineration, controlled.
X		Phenolic tars	Storage in drums
X		Aqueous wastes	Activated carbon adsorption, followed by biological treatment and discharge to industrial outfall
X		Brine solution from pesticide unit.	Activated carbon adsorption, followed by biological treatment and discharge to industrial outfall
X		Spent activated carbon.	On-site storage, drummed.
X		Alkaline scrubber bleed.	Biological treatment and discharge to industrial outfall.
X		Solid wastes (filter elements, packaging materials, empty containers, etc).	Contractor-operated state-licensed landfill.

*energy recovery

**capable of self-sustained combustion

The data in Table 6-1, for selected organic chemical plant sites, include hazardous waste stream and disposal process descriptions for 104 land-destined streams covered individually, and 70 land-destined streams covered collectively, to safeguard proprietary information. The majority of the streams were non-aqueous liquids, sludges or slurries; less than 30 percent were true solids. From the statistical summary presented in Table 6-2, it is evident that on-site landfill and incineration were the most prevalent practices, numerically, for the reporting organic chemical manufacturers, and were used to dispose of approximately 32 and 33 percent, respectively, of the hazardous waste streams examined. The disposal processes employed on the remaining hazardous wastes, with one exception, were divided numerically, in descending order, between recovery, contractor disposal, biological treatment and lagooning, and deep well injection. Land farming was employed for disposal of only one waste stream generated by one of the reporting companies. On-site incineration practices were split fairly evenly numerically between "controlled" and "uncontrolled" incineration. Contractor disposal practices reported were also split somewhat evenly between landfill and incineration.

Uncontrolled incineration is defined for this study as the disposal of wastes by combustion in facilities which lack treatment processes adequate for the protection of the environment from the combustion wastes. Controlled incineration is defined as the disposal of wastes by combustion, using the technology necessary to provide adequate environmental protection. The treatment processes and technology currently used in controlled incineration for protection of the environment from the combustion wastes include (but are not limited to):

> Properly designed and operated afterburners and secondary combustion systems to abate NOx emissions; settling chambers, impingement and cyclone separators, bag filters, electrostatic precipitators, packed towers, and spray chamber, venturi and cyclone scrubbers for the removal of particulate and gaseous contaminants from the incinerator vent gases; and evaporators, ponds, lagoons, land farms and chemical landfill for ash, collected particulate material, and scrubber liquid wastes not suitable for recovery or reuse.

The picture of organic chemicals industry practices presented in Table 6-2 under the headings "Annual Volume, Actual Tons" and "Percent of Total Annual Actual Tons" is distorted by the dilution with water used in certain instances for deep well injection. Normal biological treatment and lagooning, of course, are restricted to relatively low salinity aqueous wastes. A more accurate appraisal of the relative volumes of hazardous wastes (and their components) treated by each technique may be obtained from the data presented in Table 6-2 under the headings "Annual Volume, Estimated Dry Tons" and "Percent of Total Annual 'Dry' Tons". Uncontrolled on-site incineration was the Level I practice used to dispose of almost one-half (48 percent) of the dry weight of the hazardous waste streams at the selected organic chemical plant sites. Controlled on-site incineration, considered to be Level II and III technology, was employed for disposal of approximately 22 percent of the land-destined process waste dry-tonnage, on-site landfill close to 15 percent, recovery about 8 percent, contract disposal slightly over 5 percent, and deep well injection only 2 percent by weight. Biological treatment and lagooning as a practice was used in less than one percent of the dry weight total of the hazardous waste streams of the reporting plant sites.

The disposal technology statistics reported are for a sampling of the organic chemicals industry, with a bias towards companies who were willing to furnish data for use in this study. Such companies represented many of the major producers, with multiproduct, high volume output at their plant sites. Some of these respondents have had an above average record of employing proper hazardous waste management technology. The somewhat high proportion of on-site incineration facilities engaged in energy recovery, and a similarly high percentage for resource recovery are possible indications of this type of bias. The proportion of "dry" discharge handled by contract disposal is thought to be somewhat lower in the sample due to this bias, than the norm for the industry, nationally. The estimated 140,000 metric tons ("dry" basis) of hazardous process wastes to the land covered in the sample are about 7 percent of the estimated organic chemicals industry national total for 1973 (2 million metric tons for process discharge of hazardous waste streams to land disposal), and are considered statistically significant from that standpoint. The geographical dispersion of the plants in the sample is also sufficient to avoid bias due to strictly local considerations.

Table 6-3 covers a similar sample of treatment and disposal practices employed in the pesticides manufacturing and formulation industries. The treatment/disposal practices listed for the 25 hazardous waste streams from pesticides manufacturing and formulation operations indicate ten of the waste streams (40 percent of the total waste streams listed) are directly or indirectly disposed of in landfills; the next three prevalent practices are incineration (16 percent), storage in drums or open piles (13 percent) and resource recovery (8 percent).

The wide variety of treatment and disposal systems in current use reflects the differences in: (1) waste stream characteristics, (2) manufacturing and formulating methods, (3) size and geographic location of the plants, and (4) applicable environmental regulations. Because of differences in waste quantities and characteristics and in plant locations and operations, it was extremely difficult to arrive at a "broad average" waste treatment/disposal method representative of the current practice at a "typical" plant within the constraints imposed on this study. It is impossible to define or prescribe a practical treatment/disposal system which would be applicable to the management of wastes at all organic chemical production sites or pesticides manufacturing/formulating plants. For example, deep well disposal which has been used successfully in some locations for the disposal of organic chemicals and pesticides wastes may not be suitable for use in other locations because of geological considerations or regulatory restrictions. Many individual pesticides and organic chemicals are manufactured at large complex chemical production facilities which also manufacture a large number of other chemicals and generate significant quantities of a variety of other wastes containing hazardous components.* In such facilities, the management of waste from a specific production operation is not usually an isolated problem requiring a separate solution, but rather an element in the total waste management plan for the facility.

With the above-mentioned limitations in mind, the analyses of the existing and applicable waste treatment/disposal technologies for 15 hypothetical "typical" plants, each producing a single commodity, are presented in Section 6.2.1. As indicated in Section 6.2, ten of the plants are samples selected from the organic chemicals industry; five are examples chosen from the pesticides manufacturing industry. For each hypothetical plant, one land-destined waste stream has been selected for detailed treatment/disposal technology evaluation in Section 6.2.1 and for cost analysis in Section 7. The assumed plant capacities and the selected waste streams and their characteristics are listed in Table 6-4.

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*Approximately 92 percent of the total production of organic chemicals and technical organic pesticides in 1973 took place at the 539 plant sites which manufactured more than one organic chemical or technical organic pesticide.

The use of off-site waste management agencies for off-site treatment/disposal of wastes is a common practice in both the pesticides and organic chemicals industries. The operation of off-site waste management centers is briefly reviewed in Section 6.2.2. The data presented in Sections 6.2.1 and 6.2.2 indicate that, for the examples selected, landfill disposal, incineration, deep well injection, lagooning, resource recovery, and chemical detoxification are the methods most widely used at on-site and off-site waste treatment/disposal facilities. A brief, general review of these treatment/disposal methods, and of the activated carbon adsorption technique (used for the removal of hazardous organic constituents from aqueous waste streams) is presented in Section 6.2.3.

It is believed that many of the described applications of ultimate disposal techniques represented real or potential hazards to the environment. The following waste management technologies, as applied to the hazardous waste streams of the sample, are considered either inadequate or of dubious adequacy for environmental protection:

1. Uncontrolled incineration. This technique was used in 1973 on almost one-half of the hazardous wastes of the organic chemicals and pesticides industries plants in the sample. It thus represents Level I technology for these industries. It afforded no protection against discharge to the atmosphere of such noxious pollutants as nitrogen oxides, sulfur oxides, carbon monoxide, hydrogen halides, residual chlorinated organics, and polynuclear aromatic hydrocarbons.

2. Landfilling at insufficiently characterized sites. Two-thirds of the hazardous wastes disposed of by landfill at the organic chemicals and pesticides plants in the sample were disposed at sites for which there was inadequate knowledge of subsurface

Table 6-4. Characteristics and Treatment and Disposal Technologies – Selected Land-Destined Waste Streams from Typical Plants

Waste Stream Number	Product	Production Rate (Metric Tons per year)	Process Flow Sheet Figure Number	Selected Waste Stream	Total Waste Quantity (Metric Tons per year)	Waste Stream Characteristics: Hazardous Components: Component	Quantity (Metric Tons per year)	Other Components: Component	Quantity (Metric Tons per year)	Treatment and Disposal Technology
1	Perchloroethylene	15,[illegible]	5-1	Liquid heavy ends from perchloroethylene column	[illegible]	Hexachlorobutadiene Hexachlorobenzene Chloroethanes Chlorobutadienes Tars and residues	[illegible]	Unknown	[illegible]	Level I - Deep well injection Level II - Controlled incineration Level III - Controlled incineration
2	Nitrobenzene	20,[illegible]	5-2	Liquid still heavy ends	50	Nitrobenzene heavy ends	50	-	-	Level I - On-site landfill Level II,III - Controlled incineration
3	Chloromethane Solvents	50,000	5-4	Solid tails from solvent recovery system	[illegible]	Hexachlorobenzene, crude hexachlorobutadiene and other chlorinated paraffins	[illegible]	-	-	Level I - Contractor landfill Level II - Controlled incineration Level III - Controlled incineration
4	Epichlorohydrin	75,000	5-7	Liquid heavy ends (still bottoms)	3,971	1,2,3-trichloropropane Tetrachloropropyl ethers, dichloropropanol (dichlorohydrins) Epichlorohydrin Chlorinated aliphatic and alcohols	[illegible]	Water and unidentified products	[illegible]	Level I - On-site storage Level II - Controlled incineration Level III - Controlled incineration
5	Toluene diisocyanate	22,[illegible]	5-11	Centrifuge residue sludge	[illegible]	Lower polyurethane polymers and tars Ferric chloride Waste isocyanates	[illegible]	Unknown	[illegible]	Level I - On-site landfill, drummed Level II - Controlled incineration Level III - Controlled incineration
6	Vinyl Chloride Monomer	[illegible]	5-14	Liquid heavy ends from still	3,800	Halogenated aliphatic hydrocarbons Tars	[illegible]	Inorganics	[illegible]	Level I - Contractor incineration Level II,III - Controlled incineration
7	Methyl Methacrylate	[illegible]	5-15	Liquid heavy ends from methanol recovery	4,720	Lower methacrylate polymers Hydroquinone	[illegible]	-	-	Level I - Uncontrolled incineration Level II,III - Controlled incineration
8	Acrylonitrile	[illegible]	5-16	Liquid heavy impurities (still bottoms)	[illegible]	Higher nitriles and polymers	[illegible]	-	-	Level I - Uncontrolled incineration Level II,III - Controlled incineration
9	Maleic Anhydride	11,[illegible]	5-17	Sludge and residue (distillation column bottoms)	[illegible]	Maleic anhydride Tars, fumaric acid, and chromogenic compounds	[illegible]	-	-	Level I - Landfill Level II,III - Secured landfill
10	Lead Alkyls	[illegible]	5-19	Lead sludge from settling basin	[illegible]	Lead carbonate, hydroxide and other compounds and lead organics	[illegible]	Water, sodium chloride, and sodium [illegible] borate	[illegible]	Level I - Incineration, with lead recovery as slag Level II,III - Controlled incineration with lead recovery.
11	Aldrin	4,[illegible]	5,23	Area and equipment washdown	[illegible]	Aldrin	[illegible]	Water and dissolved salts	[illegible]	Level I - Lined pond Level II,III - Lined pond
12	Atrazine	20,000	5-24	Scrubber spent alkali solution	[illegible]	Cyanuric acid Insoluble residue	[illegible]	Sodium chloride Sodium hydroxide Water	[illegible] 620 [illegible]	Level I,II - Deep well disposal Level III - Chemical detoxification and deep well disposal
13	Trifluralin	10,000	5-25	Solid spent activated carbon	1,150	Trifluralin and related fluoroaromatic compounds Solvent and unreacted intermediates	[illegible] [illegible]	Activated carbon	[illegible]	Level I - Storage in rubber-lined drums Level II - Secured landfill Level III - Carbon regeneration with air pollution emissions control.
14	Parathion	20,[illegible]	5-26	Sulfur sludge from chlorination	[illegible]	Sulfur and organophosphorus compounds	[illegible]	-	-	Level I - Uncontrolled incineration. Level II,III - Secured landfill.
15	Malathion	11,[illegible]	5-27	Filter cake (semi-solid)	[illegible]	Dimethyl dithiophosphoric acid Toluene and insoluble residue products	[illegible]	Filter aid	[illegible]	Level I,II,III - Detoxification with NaOH and burial with NaOH in approved landfill

geology, ground water course locations, leaching characteristics, and run-off and drainage protection requirements. The protection afforded the environment against contamination by water-soluble or dispersible toxic materials was therefore doubtful or insufficient.

3. Deep well injection of hazardous process wastes. This method for disposal was used on 2 percent by weight of the sample plants' hazardous process wastes. The data supplied by these sample plants indicated, in general, that there was little or no knowledge of the capabilities of the injection strata to serve as adequate permanent liquid storage reservoirs or to protect developed and undeveloped mineral resources, including ground water. There was a similar lack of knowledge on the migration and chemical change characteristics of the hazardous materials injected.

The Level I treatment and disposal technologies for the 15 land-destined hazardous waste streams selected to give the composite pictures of practices in the organic chemicals and pesticides industries were heavily dependent upon the techniques described above. Uncontrolled incineration was the disposal method which represented the broad average of processes used on the hazardous wastes at typical vinyl chloride monomer, methyl methacrylate, acrylonitrile, lead alkyl and parathion plants. Landfill was the Level I technology for the typical chloromethane solvents, toluene diisocyanate, and maleic anhydride production facilities. Level I treatment for the hazardous waste streams of the typical perchloroethylene plant and of the single atrazine producer was deep well disposal.

6.2.1 Waste Stream Treatment/Disposal Technologies

The three levels of treatment/disposal technologies identified for the 15 selected hazardous waste streams are listed in Table 6-4. A brief description of the treatment/disposal technologies identified for each waste stream will follow. Estimates of the prevalence of safeguards used in disposal are contained in the descriptions, and are based upon the company supplied information (cited in Section 6.1). These estimates and data presented on treatment/disposal technolgies are based on information obtained for 1972-1974.

Waste Stream No. 1, Perchloroethylene Manufacture

This waste stream is composed of heavy ends from the perchloroethylene purification column (Figure 5-1). It is discharged from the process as a nonaqueous liquid. For a plant producing 35,000 metric tons of perchloroethylene, the estimated annual production of this waste is 10,500 metric tons. As indicated in Table 6-4, the major hazardous components of this process discharge are hexachlorobutadiene, hexachlorobenzene, chloroethanes, chlorobutadienes, and tars and residues. The Level I treatment/ultimate disposal method for this waste is admixture with a large volume of water to obtain a 0.5 percent suspension which is then injected into subsurface formations using deep wells. Desirable features and limitations and shortcomings of waste disposal by deep well injection are reviewed in Section 6.2.3. In general, deep well disposal is currently viewed by many companies and some regulating agencies as a temporary approach to waste management, and in the future, deep well disposal may have to be abandoned in favor of more ecologically acceptable alternatives. Specific limitations of deep well injection for the disposal of Waste Stream No. 1 include: (1) requirements for pretreatment, (2) uncertainties regarding the movement and ultimate fate of the waste in underground formations, (3) potential for groundwater contamination, and (4) geological requirements.

Level II technology for the disposal of Waste Stream No. 1 is controlled incineration* in combination with other organic wastes (or hydrocarbons) serving as fuels and hydrogen sources. In the presence of hydrogen-containing organics, the organic chloride in the raw waste is converted to hydrochloric acid which is captured effectively by countercurrent aqueous scrubbing of the product gas stream. Because of the chemical nature of the waste, control equipment* is included in the disposal system to abate emissions of air pollutants (e.g., hydrochloric acid fumes, particulates, etc.). Only a very small quantity of ash results from incineration of this waste. This ash is disposed of in a landfill.

Level III technology for ultimate disposal of Waste Stream No. 1 is the same as Level II technology.

The plants which produce perchloroethylene via the typical process shown in Figure 5-1 do not use plastic/concrete encapsulation or leachate treatment and collection as safeguards in landfill disposal of the heavy ends waste stream discussed above. It is estimated, based on the responses received for this study, that steel drums are used as safeguards in the disposal of approximately 20 percent of the total quantity of the heavy ends waste streams generated.

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*As defined on p. 6-11.

The use of deep well injection (Level I technology) is not considered environmentally adequate, (Section 6.2.3.) The Level II (and Level III) disposal technique employed (controlled incineration)* is considered environmentally adequate. Required implementation times for complete controlled incineration systems for heavy ends are estimated as approximately 2 to 3 years, based on engineering study requirements, equipment lead time, installation and construction periods, and anticipated start-up problems. Controlled incineration technology is suitable for retrofit to the majority of installations using Level I technology, with no impact on air, and noise problems and a possible decrease in groundwater pollution. The sampling, testing and surveillance techniques required to adequately monitor controlled incineration disposal facility operations are state-of-the-art (References 60 through 63), and are within the capabilities of current contract disposal facilities and the organic chemical companies manufacturing perchloroethylene.

Waste Stream No. 2, Nitrobenzene Manufacture

The heavy ends from the final purification step in nitrobenzene production (Figure 5-2) constitute Waste Stream No. 2. The process waste is discharged as a nonaqueous liquid containing primarily nitrated aromatics and possibly some residual inorganic salts. For an annual nitrobenzene production of 20,000 metric tons, the waste quantity is estimated at 50 metric tons per year. The waste is placed in plastic-lined drums and disposed of in an on-site landfill. This method of waste disposal, however, is not available for use in all locations. Because of the hazardous nature of the waste, only secured landfills (i.e., those which are designed and operated in a manner which provides for adequate protection against environmental contamination, Section 6.2.3) should be used.

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* As defined in p. 6-11.

As with Waste Stream No. 1, controlled incineration is the Level II and Level III treatment/disposal method for Waste Stream No. 2. Auxiliary organic fuels are not a requirement in this case. Incineration may permit recovery of thermal energy for in-plant use.

The plants which produce nitrobenzene via the typical process shown in Figure 5-2 do not use plastic/concrete encapsulation or leachate treatment and collection as safeguards in disposal of the heavy ends generated by purification of nitrobenzene. It is estimated that steel drums are used as safeguards in the disposal of approximately 30 percent of the total quantity of nitrobenzene purification column wastes sent to land disposal.

Disposal of nitrobenzene purification wastes in on-site landfills (Level I technology) is considered of dubious adequacy for environmental protection on the basis of the discussion in Section 6.2.3. Controlled incineration (the Level II and Level III technology) is considered environmentally adequate for disposal of the nitrobenzene wastes. The required implementation times for complete controlled incineration systems for nitrobenzene purification column wastes are estimated as approximately 2 to 3 years without energy recovery, and 3 to 5 years with energy recovery. There would be no impact on air and noise pollution problems and a possible decrease in water pollution as the result of the use of controlled incineration for disposal of nitrobenzene purification heavy ends, and the technology is suitable for retrofit to the installations now using Level I (landfill)technology. Current contract disposal operators and the organic chemical companies manufacturing nitrobenzene have the capabilities needed for the sampling, testing and surveillance techniques cited in References 60 through 63 for adequate monitoring of controlled incineration.

Waste Stream No. 3, Chlorinated Solvents Manufacture

Waste Stream No. 3 is the solid tails from the solvent recovery system in the production of methyl chloride, methylene chloride, chloroform, and carbon tetrachloride from methanol and chlorine (Figure 5-4). The waste is essentially crude hexachlorobenzene which cannot be further refined economically, and which also contains small quantities of hexachlorobutadiene and other chlorinated paraffins. The estimated annual quantity of waste resulting from a 50,000 metric tons per year manufacturing capability is 300 metric tons.

The Level I technology disposal method for Waste Stream No.3 . is contract disposal at an off-site landfill. Level II and Level III technologies for a waste of this nature are controlled incineration, in combination with other organic wastes (or hydrocarbons) serving as auxiliary fuel and hydrogen source.

The plants which produce methyl chloride, methylene chloride, chloroform and carbon tetrachloride (the chloromethanes) from methanol and chlorine . do not use plastic/concrete encapsulation or leachate collection as safeguards in the disposal of the solid tails from the solvent recovery system. It is estimated that steel drums are used as safeguards in the disposal of 30 percent of the solvent recovery wastes sent to land disposal.

Disposal of solvent recovery wastes generated in chloromethanes production by contract disposal at off-site landfills (Level I technology) is considered to be of dubious environmental adequacy if the disposal sites do not utilize adequate safeguards to prevent environmental contamination. Controlled incineration, the Level II and III technology employed, is considered environmentally adequate for disposal of the solid tails waste stream. The required implementation times for complete controlled incineration systems for solvent recovery wastes are estimated as 2 to 3 years. Controlled incineration is a technique suitable for retrofit to existing plants using contract disposal (Level I technology) with no impact on air and noise pollution problems, and a possible decrease in water pollution. The sampling, testing and surveillance techniques cited in References 60 through 63 for monitoring of emissions from controlled incineration facilities are within the capabilities of current contract disposal operators and the companies which manufacture the chloromethanes.

Waste Stream No. 4, Epichlorohydrin Manufacture

Waste Stream No. 4 is the liquid heavy ends from the fractionation column in the production of epichlorohydrin (Figure 5-7). Approximately 3,975 metric tons of this waste are produced in the production of 75,000 metric tons of epichlorchydrin. Major constituents of the waste are 1,2,3-trichloropropane, tetrachloropropyl ethers, dichloropropyl alcohols, epichlorohydrin and chlorinated aliphatics and alcohols. Level I disposal technology for this waste is storage in on-site storage facilities. A waste of this kind, however, can be effectively destroyed by incineration with proper control to eliminate air pollution. Level II and Level III technology for handling this waste is controlled incineration as defined on p. 6-11. The ash content from incineration would be low, and can be discharged to landfill.

The plants which use the allyl chloride process for the manufacture of epichlorohydrin do not use plastic/concrete encapsulation, leachate treatment and collection, or steel drums as safeguards in disposal of liquid heavy ends from the fractionating column. Large steel tanks are employed for storage of this waste at the plant sites.

Long-term storage in on-site facilities is environmentally adequate, but presents potential problems due to possible corrosion of the steel tanks. The use of controlled incineration* for disposal of the fractionation column heavy ends is considered environmentally adequate. The required implementation times for complete Level II/III systems for fractionation column heavy ends are estimated as approximately 2 to 3 years. Controlled incineration technology can be used at installations using long term storage, with no impact on air, water and noise problems. The companies which manufacture epichlorohydrin and the contract disposal site operators have the capabilities to perform the sampling, testing and surveillance (References 60 through 63) required to adequately monitor controlled incineration operations.

Waste Stream No. 5, Toluene Diisocyanate Manufacture

Waste Stream No. 5 is the thick liquor/semisolid waste from processing and centrifugation of still bottoms and residues from the production of toluene diisocyanate. For a production rate of 27,500 metric tons per year, the estimated annual quantity of waste generated is 588 metric tons. The wastes consist primarily of polyurethane low polymers and tars, ferric chloride, and isocyanates. Level I technology for the disposal of this waste is containerization in drums and burial in landfills. Controlled incineration in a steam generating plant (to recover thermal energy) is the Level II and Level III technology for the management of this waste stream.

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*As defined on p. 6-11.

The plants which manufacture toluene diisocyanate via the typical process shown in Figure 5-13 do not use plastic/concrete encapsulation as a safeguard in the disposal of wastes from the process. Leachate collection is employed as a safeguard on approximately 15 percent (estimated) of the wastes sent to land after centrifugation of the production stillbottoms and residues. Steel drums are employed as safeguards on approximately 25 percent (estimated) of these wastes.

Disposal of the centrifugation wastes by containerization in drums and burial in landfills is of dubious environmental adequacy if the disposal site does not utilize adequate safeguards to prevent environmental contamination. The Level II and III technology is considered environmentally adequate. The required implementation times for Level II/III disposal systems using controlled incineration in steam generating plants are estimated as 3 to 5 years. The Level II/III disposal systems can be employed in existing installations using Level I technology and will have no impact on air and noise pollution problems, and will result in a possible decrease in water pollution. The sampling, testing, and surveillance techniques required to monitor the Level II/III disposal system operations adequately are standard, current state-of-the-art, available from the literature,(60-63) and within the capabilities of the toluene diisocyanate manufacturers.

Waste Stream No. 6, Vinyl Chloride Monomer Production

Waste Stream No. 6 is the liquid heavy ends from the ethylene dichloride recovery still used in the production of vinyl chloride monomer (shown as Stream No. 4 in Figure 5-14). For a production rate of 100,000 metric tons/year, the estimated annual quantity of this waste is 3,800 metric tons. The major hazardous components of the waste are 1,1,2-trichloroethane, 1,1,1,2-tetrachloroethane, 1,2-dichloroethane, and tars. Contractor incineration* is the Level I technology for the disposal of this waste. Controlled incineration either on-site or off-site (by a disposal contractor) is the Level II and III technology for the management of this waste stream.

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* Uncontrolled incineration, as defined on p. 6-11.

None of the plants which manufacture vinyl chloride monomer by the use of the typical process shown in Figure 5-14 employ plastic/concrete encapsulation or leachate collection as disposal safeguards. The disposal of approximately 30 percent (estimated) of the liquid heavy ends discharged from the ethylene dichloride recovery stills is protected by the use of steel drums.

The Level I technology (uncontrolled incineration by a disposal contractor) is not considered environmentally adequate. The Level II/III technology, controlled incineration, is considered environmentally adequate for use at either on-site or off-site disposal facilities. The required implementation times for complete controlled incineration systems for recovery still residues are estimated as 2 to 3 years. Level II/III disposal systems can be retrofitted to existing installations using Level I technology and will have no impact on water and noise pollution problems, and will cause a decrease in air pollution. The sampling, testing and surveillance techniques required to monitor the Level II/III disposal system operations adequately are standard, current state-of-the-art, available from the literature (60-63) and are within the capabilities of disposal contractors and vinyl chloride monomer manufacturers.

Waste Stream No. 7, Methyl Methacrylate Manufacture

This waste stream is the liquid heavy ends from the methanol recovery section of the methyl methacrylate production unit (Figure 5-15.) The waste consists of methacrylate polymeric matter and hydroquinones. For a plant with a production capacity of 55,000 metric tons per year, the annual quantity of waste produced is estimated at 4,730 metric tons per year. The Level I technology for the disposal of this waste is uncontrolled incineration. Controlled incineration is the Level II and Level III technology used for management of this waste.

As indicated in Figure 5-15, a major waste stream in the production of methyl methacrylate is the spent sulfuric acid from acid stripper columns. The spent acid is neutralized with ammonia and processed to recover ammonium sulfate. However, if the spent acid can be pyrolyzed (using auxiliary fuel) to recover sulfuric acid for reuse, it may be possible to dispose of Waste Stream No. 7 by combustion in the sulfuric acid regeneration system. It is not known whether this approach has been tried, and sufficient analytical data are not available to evaluate the technical and economic feasibility of such an approach.

Plastic/concrete encapsulation and leachate treatment are not used as safeguards in the disposal of heavy ends from the methanol recovery sections of methyl methacrylate production units. It is estimated that steel drums are used as safeguards in the disposal of approximately 20 percent of these wastes.

Uncontrolled incineration (Level I disposal technology) is not considered environmentally adequate, on the basis of the discussion cited in Section 6.2.3 . The Level II/III technology employed (controlled incineration*) is considered environmentally adequate. Required implementation times for controlled incineration systems for methanol recovery wastes are estimated as 2 to 3 years. The Level II/III technology can be retrofitted to installations which use Level I technology, with no impact on water and noise pollution problems, and a decrease in air pollution. The techniques needed for sampling, testing, and surveillance required to adequately monitor controlled incineration facilities are known, state-of-the-art, and are within the capabilities of the companies which manufacture methyl methacrylate.

Waste Stream No. 8, Acrylonitrile Manufacture

Waste Stream No. 8 is the liquid heavy ends from the product column in the manufacture of acrylonitrile by the Sohio Process (Figure 5-16). Approximately 160 metric tons of this waste are produced in the manufacture of 80,000 metric tons of acrylonitrile. The waste stream contains polymeric matter and higher nitriles. The Level I technology for the disposal of this waste is incineration without the use of control equipment. Level II and Level III technology is incineration with the use of adequate control equipment* to remove air pollutants.

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*As defined on p. 6-11.

The plants which use the Sohio Process for the manufacture of acrylonitrile do not employ plastic/concrete encapsulation or leachate collection as safeguards in the disposal of product column heavy ends. It is estimated that steel drums are used as safeguards in the disposal of approximately 50 percent of these wastes.

Uncontrolled incineration, the Level I technology, is not considered environmentally adequate for disposal of product column heavy ends, on the basis of the discussion in Section 6.2.3. Controlled incineration,* employed as the Level II and III technology, is considered environmentally adequate. Required implementation times for complete controlled incineration systems for heavy ends from the product columns are estimated as 2 to 3 years. Controlled incineration techniques can be retrofitted to the plants which use Level I technology, with no impact on water and noise pollution problems, and a decrease in air pollution. References 60 through 63 describe the sampling, testing and surveillance techniques required to adequately monitor controlled incineration systems; these techniques are within the capabilities of the companies which manufacture acrylonitrile.

Waste Stream No. 9, Maleic Anhydride Manufacture

This waste stream is the bottoms from the distillation column in the production of maleic anhydride (Figure 5-17). Maleic anhydride, tar, fumaric acid and chromogenic compounds are the major constituents of this waste. The quantity of waste generated is estimated at 333 metric tons per year for a plant with an annual maleic anhydride production of 11,000 metric tons. The Level I technology for the disposal of this waste is landfilling.

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*As defined on p. 6-11.

The waste, however, is suitable for combustion. Controlled combustion is the Level II and Level III technology for the management of this waste. A new maleic anhydride production facility, which is being constructed by one chemical company, will use a proprietary solid catalyst. Butane is used as the raw chemical feedstock and the system design reportedly incorporates a "built-in" incinerator which will dispose of waste "internally." Details of the process and the design criteria for the system are not disclosed.

The plants which produce maleic anhydride by vapor phase catalytic oxidation of benzene do not employ plastic/concrete encapsulation or leachate collection as disposal safeguards. It is estimated that steel drums are used as a safeguard in handling 5 percent of the distillation column residues (bottoms).

The landfill disposal technique (Level I technology) used on distillation column residues is not considered environmentally adequate on the basis of the discussion in Section 6.2.3. Controlled incineration* for disposal of these maleic anhydride process wastes is considered environmentally adequate. The required implementation times for complete controlled incineration systems are estimated as approximately 2 to 3 years. Controlled incineration for disposal is a technology suitable for use at installations currently using Level I technology, with no impact on air and noise pollution problems, and a possible decrease in ground water pollution. The sampling, testing and surveillance techniques required to monitor controlled incineration disposal facility operations are described in the literature.(60-63) These techniques are current state-of-the-art and are within the capabilities of contract disposal operators and the companies which manufacture maleic anhydride.

Waste Stream No. 10, Lead Alkyls Manufacture

Waste Stream No. 10 is the sludge precipitated after alkaline ozonization of the aqueous effluent from steam stripping purification of lead alkyls

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*As discussed on p. 6-11.

(tetraethyl lead and tetramethyl lead, Figure 5-18). The highly dangerous components of this waste stream are the inorganic and organic lead salts (present in the precipitate). This sludge, which contains close to 80 percent water, is dewatered and incinerated to recover lead for reuse. The operation is incorporated into the main lead recovery system for the process or is conducted in a separate furnace. The sludge incineration process in Level I technology does not utilize equipment for control of air pollutant emissions. Particulate emission recovery and control equipment* is included in Level II and Level III technologies.

It is believed that none of the plants which produce lead alkyls use plastic/concrete encapsulation, leachate collection, or steel drums as safeguards in disposal of the sludge precipitated by ozonization.

The uncontrolled incineration process used for lead recovery (Level I technology) is not considered environmentally adequate due to the discharge of lead and lead oxide particulates to the atmosphere. Controlled incineration* (Level II and Level III technology) is environmentally acceptable. The Level II/III technology is suitable for retrofit to existing installations using Level I technology with no impact on water and noise pollution problems, and a decrease in air pollution. The sampling, testing and surveillance techniques required to adequately monitor controlled incineration are described in the literature (60-63). These are current state-of-the-art, and are within the capabilities of the lead alkyl manufacturers.

Waste Stream No. 11, Aldrin Manufacture

Waste Stream No. 11 is the land-destined aqueous waste water resulting from floor washing and spill clean-up activities in the aldrin manufacturing plant (currently inactive). For a plant capacity of 4,500 metric tons per year, the average rate at which this wastewater is generated is estimated at 550 liters per minute. Since aldrin is practically insoluble in water, nearly all aldrin in this waste stream (estimated at 0.01 percent) is present as a suspension. Nonhazardous constituents of this waste stream include water and the inorganic dissolved solids originally present. The Level I disposal technology for the waste stream is solar evaporation in an asphalt-lined evaporation basin. When a sufficient quantity of sludge is accumulated in the pond, the sludge is removed and disposed of by incineration. The area surrounding the pond is contoured to prevent the surface runoff from entering the pond. The use of lined evaporation ponds is also considered to represent Level II and Level III treatment/disposal technology for the one plant which formerly manufactured aldrin. The plant is located in an area with a high rate of evaporation, and has an adequate amount of reasonably inexpensive land for the use of this technique.

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*As discussed on p. 6-11.

The plant which produced aldrin did not use plastic/concrete encapsulation, collection of leachate, or steel drums as disposal safeguards for Waste Stream No. 11. (The wash-down and spill clean-up waste water which constituted Waste Stream No. 11 is not considered leachate). Disposal of the wastewater by evaporation in lined ponds is considered environmentally adequate for the site where the technique was used. Aldrin is no longer manufactured, and there will be no need for retrofit, or the use of sampling, testing and surveillance methods to monitor adequacy of disposal.

Waste Stream No. 12, Atrazine Production

Waste Stream No. 12 is the aqueous brine solution from neutralization and scrubbing of the effluent waste stream from the cyanuric chloride unit in atrazine production (Figure 5-24). Approximately 224,600 metric tons per year of this waste are produced in a plant with an annual atrazine output of 20,000 metric tons. The major hazardous constituents of the waste stream are cyanuric acid (resulting from alkaline hydrolysis of cyanuric chloride), insoluble by-product residues (cyamelide, etc.) from cyanuric chloride hydrolysis and excess sodium hydroxide. The treatment/disposal method employed as Level I and Level II technology for this waste stream is preliminary treatment (pH adjustment and filtration) followed by deep-well injection. The very high concentration of sodium chloride in the waste stream results mainly from the neutralization of hydrochloric acid fumes from the cyanuric chloride unit. Chemical detoxification by ozonization followed by deep well injection is considered Level III technology. Due to the extremely large volume of Waste Stream No. 12, and the locations of the atrazine plants (Louisiana and Alabama), the use of lined evaporation ponds is not feasible.

It is believed that none of the plants that produce atrazine employ plastic/concrete encapsulation, leachate collection, or steel drums as disposal safeguards for Waste Stream No. 12.

The Level I/II treatment/disposal method (deep well injection subsequent to pH adjustment and filtration) is considered of dubious environmental adequacy on the basis of the discussion in Section 6.2.3. Complete detoxification by ozonization followed by deep well injection of the neutral, filtered brine into a suitable geological strata would be considered environmentally acceptable. Times required for implementation of Level III technology are 1 to 2 years. The Level III technology is suitable for retrofit to existing atrazine plants which use Level I/II technology, with no impact on air and noise pollution problems, and a possible decrease in groundwater contamination. The sampling, testing, and surveillance techniques required for adequate monitoring would involve drilling monitor wells (2), and periodically testing composite samples taken from the wells (60), for increases in sodium chloride contents as evidence of undesirable waste brine migration. In addition, daily composite control samples (60) would be required of the well-feed to check for complete detoxification. The company currently manufacturing atrazine has the capabilities needed for sampling and testing; drilling monitor wells would provide the means for surveillance.

Waste Stream No. 13, Trifluralin Manufacture

Waste Stream No. 13 is the spent activated carbon resulting from activated carbon absorption treatment of the brine wastewater from trifluralin production (Figure 5-25). The spent carbon is not regenerated and is stored in plastic-lined steel drums. It is estimated that for an annual trifluralin production of 10,000 metric tons, approximately 600 metric tons of spent carbon is produced which contains about 93 metric tons of trifluralin and related fluoroaromatic compounds and 453 metric tons of unreacted intermediates and solvents.

On-site storage of spent carbon in steel drums (Level I technology) is only a short-term solution for the one plant which produces trifluralin. Until thermal regeneration of spent carbon (Level III technology — see below) is successfully demonstrated on a pilot-scale or full-scale unit, an interim solution involving disposal of carbon in a secured landfill (as defined in Reference 2) or secured storage area (e.g., in concrete trenches) represents Level II technology.

As discussed later in this section, activated carbon used for the treatment of municipal wastewaters and most industrial liquid wastes can be regenerated thermally with very little loss in adsorption capacity and no more than 10 percent loss of carbon. Spent carbon from treatment of trifluralin waste should be amenable to thermal regeneration, provided that the regeneration furnace and its auxiliary equipment are constructed of suitable material to withstand the corrosive hydrogen fluoride fumes which are released. Adequate control equipment* should also be provided to scrub the effluent gases from the furnace. Some pilot-plant studies may be needed to define optimum operating conditions and abatement needs for carbon regeneration. Regeneration and reuse of spent carbon thus may be considered as Level III technology for the management of Waste Stream No. 13.

The plant which manufactures trifluralin does not use leachate collection or plastic/concrete encapsulation as safeguards in the disposal of spent activated carbon. All of the spent activated carbon wastes are placed in steel drums as a disposal safeguard.

The Level I disposal technology used on the spent activated carbon is considered environmentally adequate, but impractical from a long-term standpoint. Disposal of activated carbon by storage in concrete trenches is also considered environmentally adequate, but represents only an interim solution. Recovery of the activated carbon by thermal regeneration, using the equipment described on p. 6-11 for control of pollution from incinerators, is considered environmentally adequate and the long-term technique.

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*As defined for controlled incineration on page 6-11.

The period required for implementation of Level III technology is estimated as 3 to 5 years. The thermal regeneration technology can be retrofitted to the existing plant, without impact on air, water, and noise pollution problems. The sampling, testing and surveillance techniques required for adequate monitoring of thermal regeneration are described in the literature,(60-63) and are within the capabilities of the company manufacturing trifluralin.

Waste Stream No. 14, Parathion Manufacture

Waste Stream No. 14, the sludge discharged from the chlorinator unit in the production of parathion (Figure 5-26), is an acidic sludge containing elemental sulfur and organophosphorus compounds as major impurities. This sludge is disposed of by incineration (Level I technology) without any controls for abatement of SO_2 and phosphorus oxide emissions. For a production rate of 20,000 metric tons per year, the quantity of sulfur in the sludge is estimated at 2,300 metric tons per year.

Direct recovery of sulfur from the sludge is uneconomical. Abatement of air pollutant emissions by conventional techniques is also unattractive since it produces a different type of sludge or an aqueous waste which has to be processed and disposed of. Addition of excess alkali (lime) to the waste sludge and disposal of the product in a properly designed and operated landfill represent the Level II and III technologies.

The plants which produce parathion do not use plastic/concrete encapsulation or leachate collection as safeguards in the disposal of chlorinator waste sludges. It is estimated that steel drums are used as safeguards in the disposal of 15 percent of Waste Stream No. 14.

The use of incineration without controls for abatement of SO_2 and phosphorus oxide emissions to the atmosphere is not considered environmentally acceptable. The Level II/III disposal technology (detoxification with excess lime followed by disposal in a secured landfill) is considered environmentally adequate. Required times for implementation of Level II/III technology is estimated as less than 1 year. The detoxification-secured landfill technology is suitable for use by existing plants which use Level I technology, with no impact on water and noise pollution problems, and a decrease in air pollution. The sampling, testing and surveillance techniques are given in part in Reference 2. Monitor wells peripheral to the landfill sites are also required, as are routine, periodic chemical tests of composite samples taken daily from the wells. The companies manufacturing parathion have the required capabilities and sampling and testing facilities.

Waste Stream No. 15, Malathion Manufacture

This waste stream is a semisolid filter cake waste resulting from the filtration of dimethyldithiophosphoric acid. For an annual production rate of 14,000 metric tons per year, the quantity of the filter cake waste is estimated at 1,826 metric tons per year, consisting of 1,000 metric tons of filter aids, 70 metric tons of dimethyldithiophosphoric acid and 756 metric tons of toluene and insoluble reaction products. The practice for management of this waste stream involves detoxification by treatment with sodium hydroxide and burial in an secured landfill (Level I technology). Level II and III technologies for the management of this waste are considered to be the same as that of Level I.

The plants producing malathion do not use plastic/concrete encapsulation or leachate collection as safeguards in the disposal of the filter cake wastes from filtration of dimethyldithiophosphoric acid. Use of steel drums as safeguards is estimated to be used for approximately 10 percent of the waste.

The common disposal technology used for Level I, II and III is environmentally acceptable. The time required for substitution to plants using other techniques is estimated as less than 1 year. The detoxification-landfill disposal method would be without impact on air, water and noise pollution problems. The sampling, testing and surveillance techniques are given in part in Reference 2. Monitor wells peripheral to the landfill sites are required with routine, periodic chemical tests of composite samples taken from each well to determine the leaching characteristics from the site. The companies manufacturing malathion have the required capabilities and sampling and testing facilities.

6.2.2 "Off-Site" Contract Disposal in the Organic Chemicals and Pesticides Industries

Many of the plants in the organic chemicals and pesticides industries dispose of at least a portion of their wastes at off-site facilities operated by private waste management agencies and contractors. Some of these waste management contractors also operate a fleet of trucks and provide services for waste collection and transfer to the disposal site. Depending on the processing/disposal/recovery technologies used, nearly all "off-site" waste management centers place certain restrictions on the types of wastes which they accept. Table 6-5 presents distributions by state of the off-site disposal sites and the type of wastes accepted.(64)

A variety of treatment/disposal methods are employed at off-site facilities. Some sites specialize in the recovery of salable products from certain classes of wastes (e.g., heavy metal sludges, oily wastes); the residual wastes from the recovery operation are forwarded to another facility for further processing and/or ultimate disposal. The treatment/disposal methods at some sites are fairly elaborate and consist of a variety of operations including chemical treatment, deep well disposal, landfill, biological treatment, resource recovery and incineration.

Table 6-6 lists distribution by states of treatment/disposal methods employed at off-site hazardous waste management sites. The data in this table indicate that disposal in landfills is by far the most prevalent method of ultimate disposal and is practiced at an estimated 32 sites. Incineration and deep well disposal are practiced at 20 and 6 sites, respectively. The estimated number of sites which practice some sort of resource recovery is 22; 23 sites provide some sort of chemical processing (neutralization, precipitation, oxidation, etc.). Biological treatment, lagooning, and ocean disposal are practiced by ten, four, and two facilities, respectively. An estimated total of 17 off-site facilities act merely as transfer agents and do not provide for ultimate disposal of the waste. These transfer agents may possibly employ certain preliminary processing steps (blending, concentrating, neutralizing, etc.) to obtain a product or products which can be transported more easily or sold to other agencies/sites for treatment/disposal.

Table 6-5. Off-Site Contract Disposal Sites* and Types of Wastes Accepted(64)

			NUMBER OF FACILITIES ACCEPTING DIFFERENT TYPES OF HAZARDOUS WASTES														
EPA Region	State	NUMBER OF OFF-SITE HAZARDOUS WASTE MANAGEMENT FACILITIES	CAUSTICS	ACIDS	HEAVY METAL SOLUTIONS	CYANIDES	SOLVENT/ CLEANERS	HALOGENATED HYDROCARBONS	STILL AND TANK BOTTOMS	PAINT SLUDGES	SLUDGES WITH HEAVY METALS	ARSENIC	OILY WATER	OIL WASTES	RADIOACTIVE	PESTICIDES	EXPLOSIVES
4	Alabama																
10	Alaska																
9	Arizona																
6	Arkansas																
9	California	11	6	6	7	2	6	5	6	5	6	2	6	6		7	1
8	Colorado																
1	Connecticut																
3	Delaware																
3	District of Columbia																
4	Florida																
4	Georgia																
9	Hawaii																
10	Idaho	1	1													1	
5	Illinois	2	1	1	1	1	1	1	1	1	2		1		1	2	
5	Indiana	3	2	2	2	1	2	2	3	3	1	1	1	1		1	
7	Iowa																
7	Kansas																
4	Kentucky	3	1	1			1		1	1			1				
6	Louisiana	1	1	1		1	1	1	1	1	1		1	1		1	
1	Maine	1	1	1	1		1	1	1	1	1		1	1		1	
3	Maryland	2		1	1		2										
1	Massachusetts	2	1	1	1		2	1	1			1	2	2			
5	Michigan	5	3	3	3	3	1	1	1	2	2		2	1	1		
5	Minnesota	1			1	1			1	1	1						
4	Mississippi																
7	Missouri	2	2	2	2	2	2	2	2	2	2	2					
8	Montana	2							2	2	2	2	2				
7	Nebraska																
9	Nevada	1					1									1	
1	New Hampshire																
2	New Jersey	5	2	2	1	1	3	1	2	1	1		2	3		1	
6	New Mexico																
2	New York	5	2	2	2		3	3	3	2	2	2	1	1		1	
4	North Carolina																
8	North Dakota																
5	Ohio	3	2	3	3	2	2						2	1			
6	Oklahoma	2	2	2	2	2	2	1	1	1	1		2	1			
10	Oregon																
3	Pennsylvania	2			2	1					3	1	1				
2	Puerto Rico																
1	Rhode Island																
4	South Carolina																
8	South Dakota																
4	Tennessee																
6	Texas	4	2	1	1	2	3		2	1	2		4	4		2	
8	Utah																
1	Vermont																
3	Virginia	1					1		1								
10	Washington	3	1	2	3		3	2		1	1		1	1			
3	West Virginia																
5	Wisconsin	2			2		2							1			
8	Wyoming																
NATIONAL TOTALS		64	30	33	35	22	41	23	29	25	29	11	30	25	3	22	1

REGION TOTALS																
1	3	2	2	2		3	2	2	1	1	1	2	3		1	
2	10	4	4	3	4	6	6	5	3	3	2	3	4		2	
3	5		4	3	1	3		1		3	1	1	1			
4	3	1	1			1		1	1			1				
5	16	8	6	12	5	10	4	6	7	6	1	6	4	2	4	
6	7	5	6	3	5	6	2	4	3	5		7	4		4	
7	2	2	2	2	2	2	2	2	2	2	2					
8	2							2	2	2	2	2				
9	12	6	6	7	2	7	5	6	6	6	2	6	6		8	1
10	4	2	2	3		3	2		1	1		1	1		1	

* Used by the organic chemicals and pesticides industries

Table 6-6. Treatment/Disposal Methods at "Off-Site" Disposal Sites *

EPA Region	State	NUMBER OF SITLS EMPLOYING INDICATED PERTINENT/DISPOSAL METHOD								
		LANDFILL	INCINERATION	DEEP-WELL DISPOSAL	RESOURCE RECOVERY	CHEMICAL TREATMENT	BIOLOGICAL TREATMENT	LAGOONS (PONDS)	TRANSFER	OCEAN DISPOSAL
4	Alabama									
10	Alaska									
9	Arizona									
6	Arkansas									
9	California	10	1		1	1		2		
8	Colorado									
1	Connecticut									
3	Delaware									
3	District of Columbia									
4	Florida									
4	Georgia									
9	Hawaii									
10	Idaho	1								
5	Illinois	2	1			1	1			
5	Indiana	1	2	1	3	1	1		1	
7	Iowa									
7	Kansas									
4	Kentucky	1	1			1	1			
6	Louisiana	1	1			1	1			
1	Maine								1	
3	Maryland				1	1		1	1	
1	Massachusetts	1			1	1			2	1
5	Michigan	2	2		1	4			1	
5	Minnesota		1						1	
4	Mississippi									
7	Missouri	2	2	2	2	2				
8	Montana									
7	Nebraska									
9	Nevada	1								
1	New Hampshire									
2	New Jersey	2	1		2	3	1		1	1
6	New Mexico									
2	New York		2		4	1	1		1	
4	North Carolina									
8	North Dakota									
5	Ohio	1			1	2	1			
6	Oklahoma	1		1				1		
10	Oregon									
3	Pennsylvania	2	1		1	1				
2	Puerto Rico									
	Rhode Island									
4	South Carolina									
8	South Dakota									
4	Tennessee									
6	Texas	3	4	1	2	3	3			
8	Utah									
1	Vermont									
3	Virginia		1	1						
10	Washington				2	1			1	
3	West Virginia									
5	Wisconsin	1			1	1			1	
8	Wyoming									
NATIONAL TOTALS		30	29	5	22	25	10	4	11	2

REGION TOTALS									
1	1			1	1			3	1
2	2	3		5		2		6	1
3	2	2	1	2	3		1	1	
4	1	1			1	1			
5	7	4	1	5	3	3		5	
6	5	5	2	2	4	4	1		
7	2	2	2	2	2				
8									
9	11	1		1	1		2		
10	1			2	1			1	

*Used by the organic chemicals and pesticides industries.

The fees charged for the disposal of wastes at off-site facilities vary considerably, reflecting differences in the capital invested in the facility, volume of waste handled, and operation and maintenance costs. Depending on the treatment/disposal method employed, the users charge could be based on wastewater characteristics (water content; solids content: concentration and type of specific ingredients such as cyanides, heavy metals, oil, etc.), value of the recovered product, volume of the waste, and the frequency of required service. For aqueous wastes, the unit service charge could vary from less than $0.00264 per liter to over $0.396 per liter.* Some facilities, which also provide collection/handling services, combine the transportation and treatment/disposal costs into a single user charge for a certain radius within their service area. Other facilities separate the two items of cost in their rate quotations. For example, one company which operates burial sites for the disposal of extremely hazardous wastes (certain pesticides, heavy metals, and radioactive wastes) charges a transportation fee of $0.62 per kilometer for 18.1 metric ton truck loads, and a burial fee of $0.44 per liter.** The hauling of certain hazardous wastes requires special handling equipment and/or prior containerization/packaging. In general, the transportation cost for hazardous wastes are higher than those for nonhazardous materials due to the requirements for additional precautionary measures. When the distance to an off-site waste treatment/disposal center is significant, the transportation cost may account for a significant portion of the disposal cost.

In collecting data for use in this study, three off-site hazardous waste management facilities were visited. The three facilities (located in California) are: Omar Industrial Pumping in Chula Vista, Environmental Protection Corporation -- Bryant-Park & Associates, Inc. in Bakersfield, and Fresno County Department of Public Works in Coalinga. The three facilities specialize, respectively, in handling hazardous liquid, oily, and pesticide wastes. The treatment/disposal methods employed at these sites are:(1) evaporation ponds and sludge disposal by landfilling at the Chula Vista site, (2) land spreading and microbial degradation in the soil at the Bakersfield site, and (3) landfill at the Coalinga site. The techniques used for site selection, operation and monitoring represent examples of good practices

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*$0.01 per gallon to over $1.50 per gallon

**Respectively, $1.00 per mile, 40,000 pound and $1.25 per cubic foot for all operators of lagoons, evaporative ponds, land farms, and landfills for the organic chemicals and pesticides industries. The techniques and their applications at the three sites are as follows.

The Omar Industrial Pumping disposal site (now about 15 years old) handles only liquid wastes, approximately 98 percent of which are picked up at the source by Omar-owned trucks. The waste materials include industrial process acids, alkalies, and oily wastes; company policy is to avoid more hazardous materials such as pesticides, beryllium, cyanides, flammables, explosives and radioactive substances. However, certain of these materials (liquid or solid) are picked up by the company and transferred to the San Diego County disposal site or the Nuclear Engineering Company site in Beatty, Nevada. The total quantity of wastes handled at the Omar facility averages 988,400 liters per month (261,100 gallons per month.) There are six disposal lagoons which have been either sunk in natural bentonite or lined with a 0.9-meter thickness of that material. Each lagoon has a capacity of about 1,590,000 liters (420,000 cubic feet). A series of observation holes which are located downhill from the lagoon and extend to a level below the base of the lagoon are routinely monitored for the detection of any waste which may infiltrate into the subsurface formations,Regional Water Quality Board monitors the observation boreholes, and to date, no fluid has been detected in any of these holes. Solidified waste from the filled lagoons is landfilled in an adjacent area underlain with an 18.29-meter (60-foot) seam of impermeable clay. The site's 15-year operation has been trouble-free; there have been no fires, explosions or spills at the site.

The Bryant-Park Associates Westside site and the Environmental Protection Corporation Eastside site have both been developed to handle liquid organic wastes from the oil industry. These wastes are grouped into six categories: oil sump sludge, oil field brine, rotary mud, tank bottom sediment, service station waste and "other." No pesticides or inorganic wastes are accepted by either site, and both are licensed as California Class I (Appendix B) with additional development. As the Eastside site has significant potential for later development as a residential area, operations are geared to this objective and include filling of canyons with stabilized soil. The disposal farming technique practiced at the Westside site involves spreading the liquid wastes on the land directly from tank trucks. The earth is then disked under and the waste is worked into the soil.

The farming technique at the Eastside site uses the "flooding" method whereby a plot of land (0.4 to 1.6 hectares) is flooded with the wastewater and allowed to remain idle until most of the water is evaporated. The area is then plowed, and replowed as necessary thereafter, to assure adequate aeration and rapid degradation of the oily waste. Waste-receiving plots are rotated to assure continuity of operation. In both the "flooding" and "spreading" methods, the quantities of wastes applied to the soil are carefully controlled to assure the maintenance of aerobic conditions within the disposal layer (generally, the upper 15 centimeters (6 inches) of soil). The state of degradation of the waste is assessed through changes in soil texture and provides a good indication of the readiness of the land for reuse. The quantities of wastes which have been handled at the two sites are 85,200,000 liters (536,000 barrels) and 36,000,000 liters (230,000 barrels) for Eastside and Westside, respectively.* Of these totals, the majority has been sump sludges and drilling muds with very little in the way of service station wastes and "other" wastes.

The Fresno County Department of Public Works site near Coalinga was established to provide a central location for the disposal of discarded/reject pesticides and related agricultural chemicals and the empty containers which would otherwise accumulate throughout the local San Joaquin farming area. The site is California Class I (as described in Appendix B) and consists of a 130,000 square meter (32-acre) parcel on the eastern slope of the Pacific Coast Range; the underlying strata are classified as being of "moderate to low" permeability and are not in hydraulic continuity with fresh water-bearing zones in adjacent areas. The site is only open 4 weeks per year (2 weeks in the fall and 2 weeks in the spring). The disposal procedure consists of excavating a 6-meter (20-foot) deep trench, emptying the waste material into the trench and leveling and compacting it with a bulldozer. At the end of each working day, the waste is covered with 15 centimeters (6 inches) of dirt. A dirt cover of 0.6 meters (2 feet) is provided when the site is closed for the season. The gross capacity of the site is estimated at 460,000 cubic meters (600,000 cubic yards), of which only a small fraction has been used. A typical operational period (October 21 - November 1, 1974) involved the disposal of 5000 cubic meters (6600 cubic yards) of various pesticide containers; 180 metric tons (198 tons) of zinc sludge waste;

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*Based on data obtained for 1974

15.4 metric tons (17 tons) of diluted pesticide residue; and 24 cubic meters (31 cubic yards) of mercury-contaminated seed. The wastes handled are from both Fresno County and adjacent counties.

6.2.3 Prevalent Treatment/Disposal Technologies

As indicated above, the most prevalent methods for the processing/disposal of hazardous wastes from the organic chemicals and pesticides industries are landfill disposal, incineration, deep well injection, lagooning, and activated carbon absorption. The following is a brief general review of each of these methods as applied to the wastes of the industries covered in this study.

Landfill Disposal

The use of landfills is a common method for the disposal of solids, semisolids and concentrated liquid wastes from the organic chemicals and pesticides industries. In general, there are two methods of landfill disposal. In the "trench" method, a bulldozer or front-end digger is used to make trenches (about 1 to 4 meters (4 to 12 feet) deep, 4.5 to 17 meters (15 to 40 feet wide) in which the waste is deposited. The excavated material is then used as cover after the deposited material is compacted. The "area method" of landfilling is generally used when the site is considerably lower in elevation than the surrounding land. The material is deposited and compacted in the fill and covered daily with a minimum of 15 centimeters (6 inches) of compacted earth. The cover material is usually obtained from borrow pits. Most liquid wastes and some semisolid and solid wastes are "buried" in landfills in containers (e.g., 208 liter (55-gallon) drums). In some cases, liquid wastes are also disposed of in a landfill by spraying over them over the fill area or by injection into the body of the previously completed fill. Many of the highly dangerous wastes are placed in steel containers or treated to produce chemically and mechanically stable solids prior to burial in a landfill. Some liquid wastes are also containerized.

Landfills for the disposal of hazardous wastes must be located at sites with little or no possibility for groundwater contamination. Where the subsurface geological formations are not favorable, the site will have to be lined with a nonpermeable material (e.g., clay), and protected against surface runoff from the surrounding land. Depending on the nature of the wastes, soil conditions, rainfall and temperature, the waste material in a landfill may undergo chemical and biological degradation. Some landfills (the so-called "chemical" landfills) are specifically designed and operated to promote biodegradation and accelerated waste stabilization. These landfills are usually provided with a system for leachate collection. The leachate is then processed in a conventional wastewater treatment facility (e.g., an activated sludge plant) prior to final disposal.

Landfills for the disposal of hazardous wastes are generally operated under some form of a permit from a state agency. The regulations and restrictions vary greatly from state to state. The California system of landfill classification and restrictions on the kind of wastes which can be placed in each type of landfill is presented in Appendix B. In the California system, pesticides and other toxic and hazardous wastes can only be deposited in Class I disposal sites which are located in geologically suitable areas and which are designed and operated in a manner which provides for maximum environmental protection. Section 6.2.2 contains the description of a California Class I disposal site handling primarily agricultural wastes (pesticides and pesticide containers).

Incineration

Incineration is widely used in the organic chemicals and pesticides industries for the disposal of combustible solids, semisolids and concentrated liquid wastes. Properly designed and operated incinerators can provide for effective waste disposal in an environmentally acceptable manner. Incineration of most wastes results in the production of an inorganic ash, which has to be disposed of, and generation of air pollutants which must be controlled by the use of appropriate emission control equipment. Certain incineration operations are aimed at recovery of by-products for reuse. Examples of such an application include recovery of hydrogen chloride from chlorinated organic wastes and recovery of lead as slag from the lead-containing sludge obtained as wastes in the manufacture of lead alkyls. In some facilities, concentrated wastes high in calorific value are burned in the on-site power plant, thereby effecting a partial recovery of energy for in-plant use. Incineration of dilute aqueous wastes and sludges require the use of supplementary fuels to promote and sustain combustion.

To achieve complete destruction of the waste material, design and operation of incinerators should provide for:(1) adequate residence time, (2) effective mixing and turbulence, (3) sufficiently elevated temperature (760^{0}C to over 1000^{0}C), and (4) adequate amounts of oxygen for combustion. A variety of incinerator types and designs are available for the disposal of industrial hazardous wastes. Table 6-7 lists the incinerators used for the disposal of chemical plant wastes and summarizes the applications, advantages, and limitations of each type of incinerator.

Equipment requirements for control of air pollutant emissions vary for different applications, reflecting differences in waste characteristics, incinerator performance, and air pollutant emission regulations. Emissions of particulate pollutants can most effectively be controlled by the use of such devices as cyclones, bag filters, electrostatic precipitators and venturi scrubbers. Airborne emissions from combustion of wastes containing halogens, and sulfur and phosphorous compounds require the use of aqueous gas scrubbing (with water or an alkaline solution). Commonly used scrubbing devices include packed towers, spray towers, plate towers, and venturi scrubbers. For incinerators fed phosphorus compounds, particulate emission control devices must be used in series with the gas scrubbing equipment.

Figure 6-1 is a schematic presentation of a new 76 billion joule (72 million Btu) per hour stationary liquid waste burner at the Dow Chemical Plant in Midland. The unit is capable of burning tars (still residues, waste solvents, chemical by-products, etc.) at a rate of 34 liters per minute (9 gallons per minute). The tars are pumped to four low-pressure atomizing oil burner nozzles in a box-type combustion chamber maintained at 1080°C (1800°F). The hot combustion gases travel through a baffled quench chamber where they are cooled to 150°C (300°F). A 448 kilowatt, 2.3 meter (600 horsepower, 190-inch) fan then pulls them through a high pressure drop venturi scrubber. After passing through a packed tower, the scrubbed gases are discharged to the atmosphere through a 30-meter (100-foot)stack. More than 9,500 liters per minute (2500 gallons per minute) of water (the effluent from the primary clarification of the plant liquid wastes) are used in the scrubber to remove acid fumes and particulates.

Table 6-7. Incinerators for the Disposal of Chemical Plant Wastes*

Type	Uses and Advantages	Disadvantages and Limitations
Solid Stationary Hearth	1. Low capital. 2. Potential of tight air control with an airlock feeder. 3. Used for incineration of solids. 4. Can be designed to include liquid incineration.	1. No turbulence, mixing or aeration. 2. Slow burning rates. 3. Batch operation. 4. Manual ash removal. 5. Does not lend itself to good air pollution control.
Solid Hearth (Rotary Hearth or Rabble Arms)	1. Continuous ash discharge. 2. Capable of incinerating waste solids independently or liquids and solids in combination. 3. Widest practical turn down ratio. (Maximum to minimum operating range). 4. Incinerating materials will not fall through hearth. 5. Adaptable for use with a gas scrubbing system.	1. Rabble arms or plows are susceptible to damage. 2. Limited turbulence and air contact. 3. Partly combusted materials may flow out ash discharge. 4. Solid wastes fed at intervals. An air lock system should be used to improve combustion characteristics and control. 5. Arched, self-supported multiple hearths made of refractory material are vulnerable to abrupt temperature variations with resultant downtime and cost increase.
Rotary Kiln	1. Will incinerate a wide variety of liquid and solid wastes. 2. Capable of receiving liquids and solids independently or in combination. 3. Not hampered by materials passing through a melt phase. 4. Feed capability for drums and bulk containers. 5. Wide flexibility in feed mechanism design. 6. Provides high turbulence and air exposure of solid wastes. 7. Long inventory time for slow burning refuse. 8. Continuous ash discharge. 9. No moving parts within the kiln. 10. Adaptable for use with a wet gas scrubbing system.	1. High capital cost installation for low feed rates. 2. Cannot utilize suspended brick in kiln. 3. Operating care necessary to prevent refractory damage. 4. Airborne particles may be carried out of kiln before complete combustion. 5. Spherical or cylindrical items may roll through kiln before complete combustion. 6. Kiln incinerators frequently require excess air intake to operate due to air leakage into the kiln via the kiln end seals and feed chute, which lowers fuel efficiency. 7. Drying or ignition grates, if used prior to rotary kiln, can cause problems with plastics melt plugging grates and grate mechanisms.
Fluid Bed	1. Capable of incinerating a moderate range of liquid and solid wastes. 2. Rapid heat transfer from gas to solid. 3. High combustion rate. High turbulence and air exposure. 4. Low excess air requirements. 5. Large heat sink to smooth out fluctuations in feed rate or fuel value.	1. Requires fluid bed preparation and maintenance. 2. Feed selection must avoid bed damage. 3. May require special operating procedures to avoid bed damage. 4. Incineration temperatures limited to a maximum of about 815°C (1500°F).
Stationary Liquid Waste Burner	1. Capable of incinerating a wide range of liquid wastes. 2. May use suspended brick. 3. No continuous ash removal system required other than air pollution controls.	1. Must be able to atomize tars or liquids through a burner nozzle except for certain limited applications. 2. Heat content of liquids must maintain adequate temperatures or a supplemental fuel must be provided. 3. Must provide for complete combustion and prevent flame impingement on refractory.

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*"A Guide for Incineration of Chemical Plant Wastes", Manufacturing Chemists Association, Technical Guide SW-3, adopted April 1974.

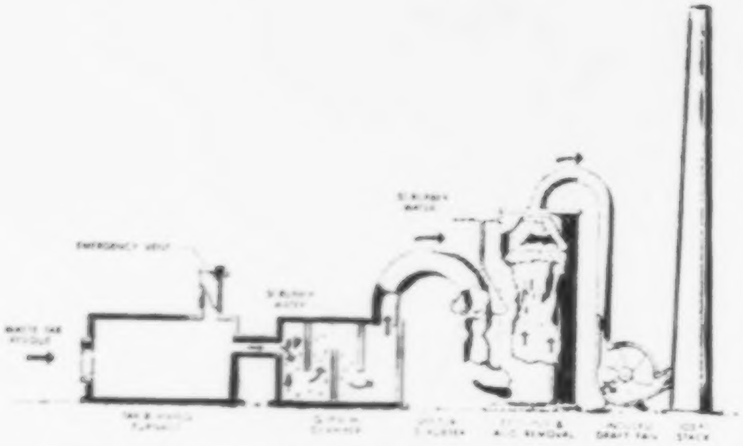

Figure 6-1. Cross Section of the New Tar Burner at Dow Chemical Midland Facility

Figure 6-2 is a schematic presentation of one of the two rotary kiln incineration systems at the Shakopee, Minnesota, facility of Pollution Controls, Inc. (a chemical waste management firm). The systems have been used for contract incineration of a variety of hazardous wastes from chemicals manufacturing plants. Each kiln is 2.4 meters (8 feet) in diameter and 12.2 meters (40 feet) long with separate venturi scrubbers followed by a Universal Oil Products Company floating bed ("bouncing ball") scrubber. The scrubbed bed exit gases go through blowers for discharge to a common stack. The kilns are unlined carbon steel shells which are cooled by external water sprays. The cooling water falls from the outer surface of the kilns directly into a sump. This water is supplemented with makeup water and returned to the spray although a portion overflows to the basins receiving water discharged from the scrubbers. The scrubber water basins are operated in a series so that the water from the second basin is recycled to the scrubbers. Scrubber water from both incinerators is discharged into the first basin and recycled from the second basin. Consequently, it will be necessary to operate only one incinerator if the changing conditions in the scrubber water system are determined. Because lime is usually used to control the pH in the scrubber loop, the basins contain large quantities of sludge which are removed periodically. This sludge is accumulated in

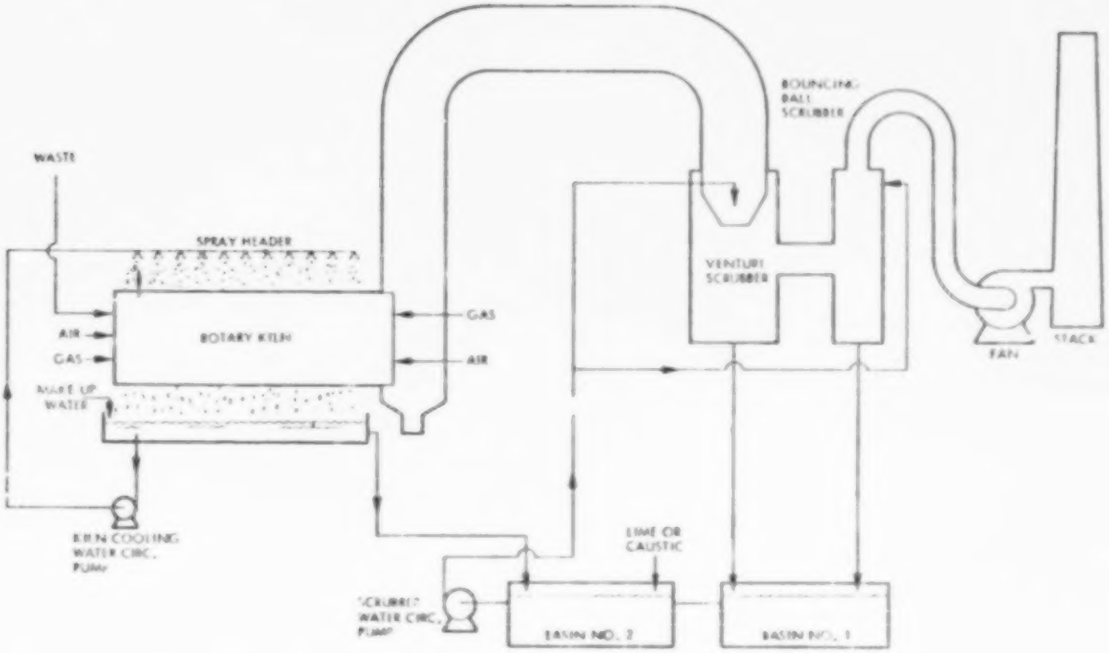
BOUNCING BALL SCRUBBER
WASTE
SPRAY HEADER
VENTURI SCRUBBER
GAS
AIR
ROTARY KILN
GAS
AIR
FAN
STACK
MAKE UP WATER
KILN COOLING WATER CIRC. PUMP
LIME OR CAUSTIC
SCRUBBER WATER CIRC. PUMP
BASIN NO. 2
BASIN NO. 1

Figure 6-2. Rotary Kiln Incinerator and Control Equipment at an "Off-Site" Disposal Facility

lined pits, prior to feeding to the incinerators. Solids discharged from the incinerators are sent to local landfills.

The wastes can be pumped into the feed end of the kiln, and solids and sludges can be introduced through an opening at the feed end of the kiln. Gas is burned as an auxiliary fuel at both the feed and exit ends of the rotary kiln. Consequently, the temperatures in the unlined rotary sections are usually maintained under 650°C (1200°F), whereas in the large run of ducting following the burner at the exit end, the temperatures may reach 1040° to 1320°C (1900° to 2400°F). The residence times in the high temperature zones are reported to be up to 2 seconds. Waste feed rates are reported to be from 2 to 4 cubic meters per hour (500 to 1000 gallons per hour); presumably feed rates could be virtually any value below the maximum rate at which complete combustion occurs, limited essentially by the automatic safety control of the burners and the temperature measurements taken at a few points in the off-gas system.

Deep Well Injection

Deep wells, in recent years, have provided an economically attractive alternative to surface treatment/disposal of wastes. Although deep wells have been extensively used in the oil and gas industry for the disposal of brine and enhancement of gas and oil yields, their use for the disposal of chemical industry liquid wastes is a relatively new practice which grew substantially in the past decade. In 1964 there were approximately 30 chemical process waste injection wells; in 1973, there were 280 chemical process waste injection wells in the United States.(1) Most of the wells are located in Texas (about 25 percent of the total), Louisiana, and Michigan. Because of uncertainties involving future regulations concerning deep well disposal, few new disposal wells are currently being constructed and some large chemical companies which used deep wells for the disposal of some of their wastes are considering alternative approaches to waste management.(1) Figure 6-3 is a schematic presentation of an injection well which is used by one company for the disposal of a concentrated organic chemical waste (14 percent organics, consisting mainly of dibasic organic acids and salts, alcohols, and aromatic compounds).(65)

A deep well disposal system can only be successful if a porous, permeable formation of wide areal extent and thickness is available at sufficient depth to insure continued, permanent storage of the injected liquid. The disposal layer should also; (1) contain no minerals of commercial value, (2) be below the lowest ground water aquifier; (3) be confined above and below by impermeable zones and (4) contain no extensive faults or other natural fractures of formations. The liquid waste to be disposed of by deep well injection must also be physically and chemically compatible with the formation. It should be completely detoxified by chemical and physical treatment prior to injection. Wastes containing significant concentrations of suspended solids or constituents which may result in the formation of precipitates and plugging of the pores in the disposal stratum require pretreatment (e.g., sedimentation, pH adjustment, filtration, etc.) prior to injection. Well construction should provide adequate protection against groundwater contamination and should include provisions for continuous monitoring of well performance and movement of the waste underground, including

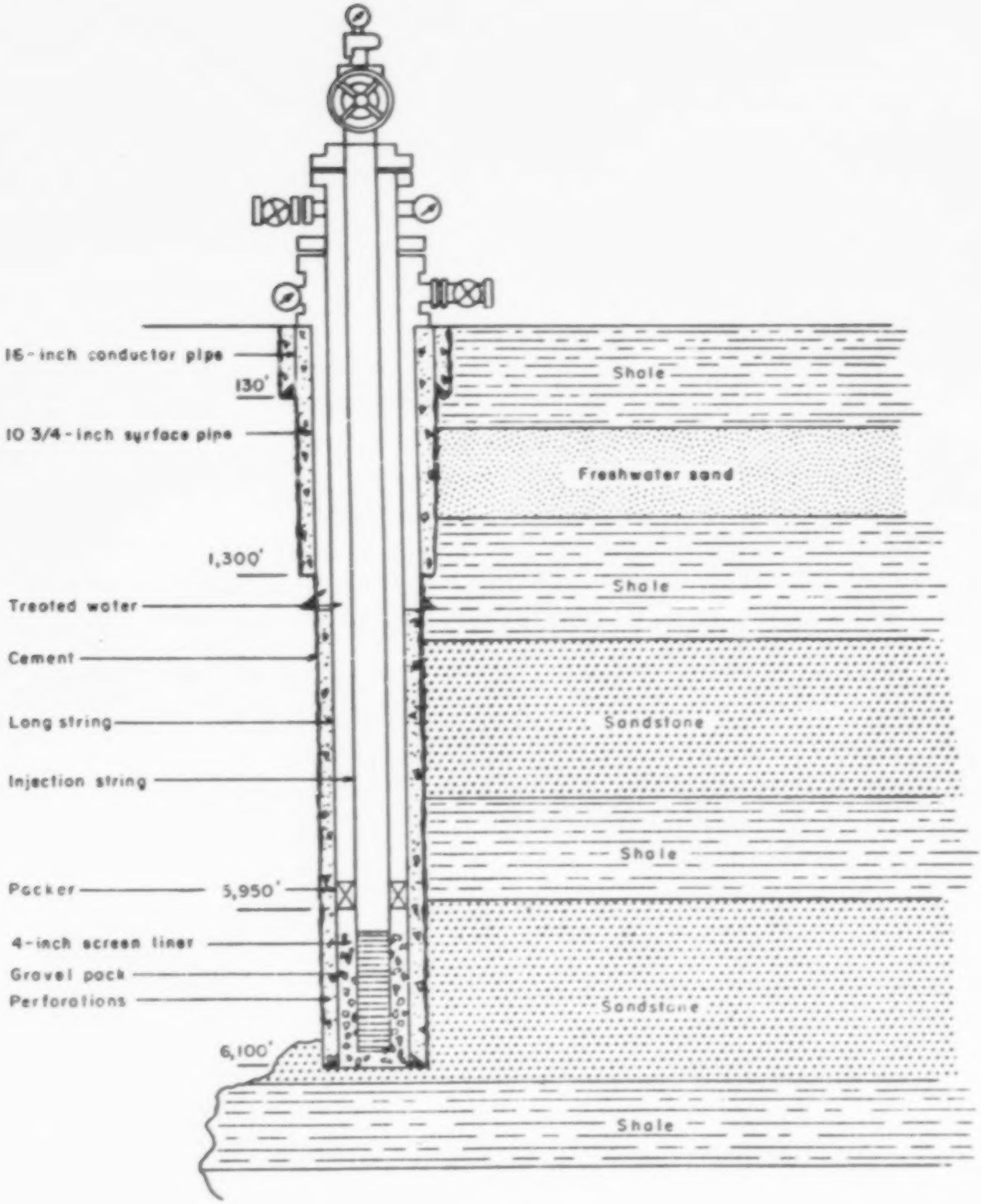
16-inch conductor pipe
130'
10 3/4-inch surface pipe
1,300'
Treated water
Cement
Long string
Injection string
Packer
5,950'
4-inch screen liner
Gravel pack
Perforations
6,100'
Shale
Freshwater sand
Shale
Sandstone
Shale
Sandstone
Shale

Figure 6-3. Injection Well Completion(65)

continuous sampling of subsurface water courses by monitor wells. Very few of the deep well treatment and disposal systems in current use meet all of these requirements.

State laws concerning deep well injection are varied. Some states (e.g., Idaho and Arizona) strictly prohibit underground waste disposal. Texas, Michigan and Ohio are the only states that have specific regulations for underground waste injection. Other states have added regulations involving underground waste injection to existing laws, or have liberally interpreted their surface and groundwater pollution laws, and in a few cases their oil and gas laws, to include subsurface injection of industrial wastes. In California, deep well injection is regulated by the State Water Resources Control Board and by the Division of Oil and Gas. Permits for deep well disposal are granted on a case-by-case basis. The Injection Well Act of the State of Texas is reproduced in Appendix B.

A 1974 U.S. Bureau of Mines Information Circular(65) provides case histories for 15 subsurface injection wells in the United States. General information on 13 of these wells handling wastes from the organic chemicals industry are summarized in Table 6-8. The systems listed in this table employ a variety of waste treatment schemes prior to subsurface injection. Significant differences also exist in the geology, well construction, injection rate and operating pressure at each site.

Evaporation Ponds

Evaporation ponds (lagoons) are used by the organic chemicals and pesticides industries for the containment/disposal of liquid wastes. These ponds are either used alone or as a final polishing step after the wastewater is processed by other methods of treatment (e.g., biological oxidation). A recent study of the pollution control technology in the pesticides formulating industry(66) indicates that solar evaporation is the most widely employed treatment technique. This same survey(66) also identifies evaporative systems with no discharge of water as the best practicable technology for the management of aqueous wastes from most pesticides formulating plants.

Table 6-8. Data on Selected Deep Well Disposal Systems(65)

Company	Location	General Nature of Operation	Waste Characteristics	Injection Zone	Surface Treatment And Equipment	Injection Rate	Injection Pressure
A	Texas Panhandle	Oil refining and petro-chemical products	High concentration of inorganic (mainly sulfates and chlorides)	Glorieta Sand 330 to 370m deep	Clarification, pH adjustment	Ave [illegible] liter/min Max [illegible] liter/min (Ave 500 gpm) (Max 750 gpm)	At ave flow: 1135 kN/m^2 (150 psi)
B	-*	Fractionation	Insoluble oily disulfide waste from a fractionating unit	Massive sandstone subsurface depth from 619 to 652m.	Surge tank (8000-gal capacity) closed to atmosphere	Ave 7.6 liter/min Max 18.9 liter/min (Ave 2 gpm) (Max 5gpm)	Gravity flow from surge tank
C	East Texas	Chemical plant	An acid waste (pH close to zero) containing about 14 inorganics and 4 organics (acids, ketones, alcohols, and peroxides)	Porous bed of the paluxy sandstone, injection depth 1173m.	Oil skimming, filtration	Ave 30 liter/min (Ave 8 gpm)	NA
D	Gulf Coast of Texas	Chemical plant	Waste containing sulfuric acid, ammonium sulfate and organics (total con. 8.2); pH: 1.5	Massive sand beds of the Frio Group; injection depth 2134-2225m.	Storage, filtration	NA	Less than 3550 kN/m^2 (500 psi)
E	Gulf Coast of Texas	Chemical plant producing chloroprene and neoprene	Alkaline waste containing 4.1 TDS (mostly sodium chloride)	Sand beds of the Frio Group; injection depth 2134-2225m.	Neutralization with HCl, sedimentation, flotation and filtration	Ave 800 liter/min Max 1700 liter/min (Ave 200 gpm) (Max 440 gpm)	NA
F	Gulf Coast of Texas	Chemical plant	Waste containing 4.3 organic compounds and 1.9 inorganic	Frio Clay at a depth of 1692 to 2118m; injection wells drilled to a depth of 2118m.	Equalization, API separation, skimming, chemical coagulation, rapid sand filtration	Ave 1500 liter/min (400 gpm) into two wells	Ave 2170-3550 kN/m^2 (300-500 psi)
G	-	"Off-site" contract disposal employing oil reclamation, incineration and deep well injection	Industrial sludges, oil and aqueous wastes	Sand and sandstone; injection tube perforated in the interval from 1615 to 1768m.	Lime treatment, sedimentation and filtration	190-380 liter/min (50-100 gpm)	790 kN/m^2 (100 psi)

* - Indicates data was not provided in cited reference
NA indicates Not Available

Table 6-8. Data on Selected Deep Well Disposal Systems(65) (Continued)

Company	Location	General Nature of Operation	Waste Characteristics	Injection Zone	Surface Treatment And Equipment	Injection Rate	Injection Pressure
H	Gulf Coast	Petroleum Refinery	Waste caustic, sour process water, anion exchange resin regeneration rinse	Sand and sandstone; casing perforated in the interval from 1981 to 2103m.	Storage facilities	Ave 1300 liter per minute	Less than 583 kN/m^2 (70 psi)
I	Gulf Coast	Polymer Production	Organic process waste containing about 5% water soluble organics after surface treatment for subsurface injection	Oakville sand; injection zone 1128 to 1219m deep.	Aeration, lime treatment, sedimentation, and dual media filtration	380-570 liter/min (100-150 gpm)	3550 kN/m^2 (500 psi)
J	Gulf Coast	Petrochemical Production	Aqueous waste from the production of glycol and acetaldehyde. Waste has a very low pH and contains primarily chlorinated aldehydes and acids, and ethylene glycols	Oakville sand injection casing set to a depth of 152m.	pH adjustment to 4.0-5.0 with alkali, filtration	830 liter/min (Ave 220 gpm)	2340 kN/m^2 (Ave 325 psi)
K	-*	Chemical plant	Aqueous process waste containing about 14% organic acids and their salts	Sandstone; disposal formation at a depth of about 1829m.	Blending, sedimentation, and filtration	570 liter/min (Ave 150 gpm)	Ave 3550 kN/m^2 anticipated maximum 17,300 kN/m^2 (2500 psi)
L	-	Chemical plant	Process waste from production of acetaldehyde, butanol hexamethylenediamine and vinyl acetate	Sand bed at a depth of approximately 1036m and about 76m thick.	Sedimentation, oil skimming, pH adjustment, filtration	800-1500 liter/min (200-400 gpm)	1480-3550 kN/m^2 (200-500 psi)
M	-	Chemical plant	Waste from terephthalic acid	Sand and sandstone; injection well drilled to a depth of 1829m.	Sedimentation, anthracite filtration	NA	NA

* - Indicates data was not provided in cited reference.
NA indicates Not Available

Depending on the wastewater volume, evaporation ponds consist of small concrete tanks, large earthen depressions or excavation basins. Unless the natural soil is reasonably impervious, earthen ponds are lined with an impervious material such as bentonite clay, asphalt, concrete, or plastic liners to prevent subsurface percolation and possible contamination of the groundwater. For larger ponds, the runoff from the surrounding areas is kept away by the use of diversion structures. Some ponds are provided with observation wells (test holes) drilled at strategic locations away from the pond for routine monitoring and detection of possible leakage into the underlying subsurface formations.

In addition to the loss of water by evaporation, and depending on wastewater characteristics, a number of other processes could be operative in an evaporation pond. These include sedimentation, biochemical oxidation, precipitation, and chemical oxidation. To increase the rate of evaporation, some ponds are provided mechanical surface aeraters or sprayers. The wastewater discharged to an evaporation pond is often subjected to pretreatment. Depending on the nature of the wastewater, the pretreatment methods used include deemulsification, oil removal and pH adjustment. Off-site disposal contractors which handle a variety of wastes originating from different industrial operations are concerned with waste compatibility and usually either operate "segregated" ponds or require proper pretreatment at the source prior to waste pick-up. When significantly large quantities of sludge accumulate in a pond, such sludge is removed and disposed of (e.g., by landfilling). When several ponds are available for use, the ponds can be operated on a "rotational" basis to provide uninterrupted operation when one or more ponds are being serviced.

Evaporation ponds can be employed most successfully in areas where relatively inexpensive land is available and where climatic conditions are conducive to a high rate of evaporation during most of the year. Possible problems associated with evaporation ponds include the potential for odor development and air pollution, seepage into the ground, and possible hazard to the wildlife. Evaporation ponds in current use in the pesticide industry vary significantly in size, depending on the wastewater volume and annual rate of evaporation.

Detailed descriptions of an "off-site" contract disposal facility in Southern California which uses evaporation ponds and disposes of the sludge by landfilling were presented in Section 6.2.2.

Activated Carbon Adsorption

Activated carbon adsorption is an effective method for the removal of organic material from a variety of industrial wastewaters. The greatest applicability of carbon adsorption is in processing waste streams which are not amenable to biological treatment because of their content of toxic chemicals and/or the refractory nature of their organic constituents. Use of activated carbon for the treatment of aqueous wastes from the organic chemicals and pesticides industries is expected to become more widespread in the future as higher levels of pollutant removal become necessary to meet stringent effluent discharge requirements. Activated carbon adsorption has been identified as the best available technology for the treatment of wastewaters from pesticides formulating plants.(66) Activated carbon adsorption can be regarded as a "land-related" waste treatment/disposal method since in some applications (e.g., processing of the brine wastewater from trifluralin manufacture) the spent carbon is disposed of by containerization and surface storage. Furthermore, the conventional thermal method of spent carbon regeneration, whereby the adsorbed organics are destroyed by pyrolysis/oxidation in a multiple hearth furnace, may be regarded as an incineration method for the destruction of organic wastes.

Both granular and powdered activated carbons have been used for waste water treatment. Powdered carbon application involves mixing the carbon with the wastewater, flocculation by the addition of a polyelectrolyte, and separation of the spent carbon from wastewater by filtration. Granular carbon adsorption essentially involves passing the wastewater through a columnar bed of carbon in an upflow or downflow fashion. Powdered carbons cannot be regenerated economically. Unless the necessary technology is developed, the application of powdered carbon to wastewater treatment will be on a once-used throwaway basis. For most applications, granular carbons can be regenerated for reuse with almost 100 percent restoration of adsorptive capacity and not more than 10 percent loss per cycle. It is because of this regeneration possibility that granular carbon is more economical than powdered carbon for wastewater treatment.

Adsorption of pollutants on activated carbon is affected by a large number of factors related to the adsorbate-adsorbent-solution properties. Because properties of activated carbon vary among different commercially available carbons, the selection of a carbon for a particular application is generally based on laboratory and pilot column tests in which the adsorptive capacity of different carbon products are evaluated and compared.

Of the several techniques tested for the regeneration of organic compound-contaminated granular carbons, thermal regeneration under controlled conditions has been found to be most economical. Thermal regeneration is usually considered a three-step process, involving: (1) drying which results in evaporation of the free water, (2) baking or pyrolysis of adsorbed organics which results in the evolution of gases and formation of carbon residues in the micropores of the activated carbon, and (3) activation or destruction of the carbon residues formed in the baking step. Drying can be accomplished at 100°C (212°F), baking between 100° to 815°C (212° to 1500°F), and activation at carbon temperatures between 815° to 900°C (1500° to 1650°F). All three steps can be carried out in a direct-fired multiple hearth furnace, which is currently regarded as the best commercially available equipment for the regeneration of carbon used in treatment of domestic and certain industrial wastewaters.

Figure 6-4 presents a schematic diagram of the carbon adsorption system at the Chipman Division of Rhodia, Inc., in Portland, Oregon. The system handles phenolic wastewaters from the manufacturing and formulation of chlorinated pesticides (see Table 6-9 for wastewater analysis). The removal efficiency for the toxic phenols is reported to be close to 99 percent. Because of the low pH of the wastewater (pH = 0.5), the carbon columns are of wood construction. Corrosion-resistant material, such as glass, fiber-reinforced plastic, special metals and acid-proof brines, is also used in certain sections of the system. Carbon regeneration is conducted in a multiple-hearth furnace with a carbon loss of about 5 percent. The exhaust gases leave the furnace at 315°C (600°F) and pass through an afterburner

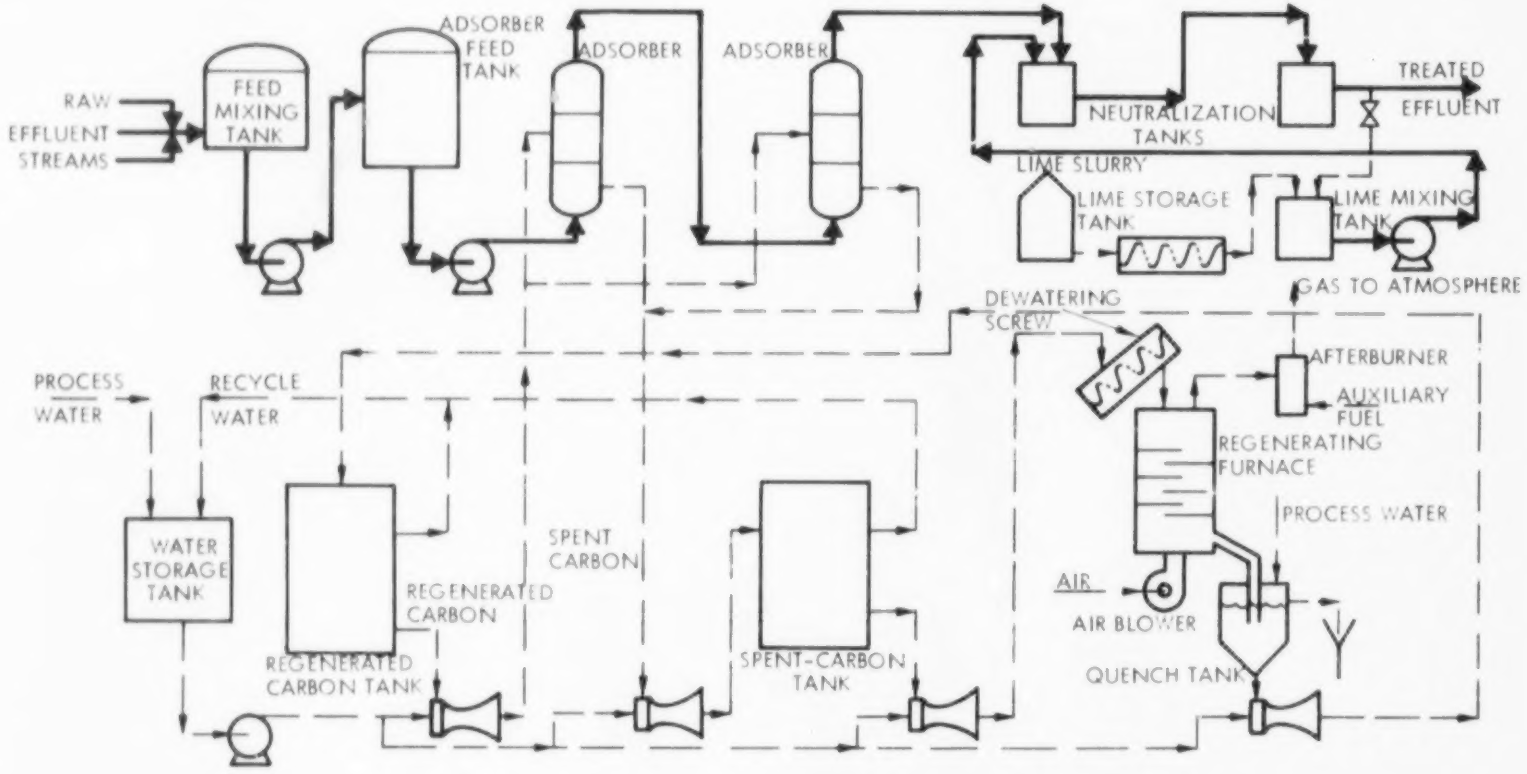
RAW
EFFLUENT
STREAMS
FEED
MIXING
TANK
ADSORBER
FEED
TANK
ADSORBER
ADSORBER
NEUTRALIZATION
TANKS
TREATED
EFFLUENT
LIME SLURRY
LIME STORAGE
TANK
LIME MIXING
TANK
GAS TO ATMOSPHERE
DEWATERING
SCREW
AFTERBURNER
AUXILIARY
FUEL
REGENERATING
FURNACE
PROCESS WATER
AIR
AIR BLOWER
QUENCH TANK
PROCESS
WATER
RECYCLE
WATER
WATER
STORAGE
TANK
REGENERATED
CARBON
REGENERATED
CARBON TANK
SPENT
CARBON
SPENT-CARBON
TANK

Figure 6-4. Portland Waste Treatment Plant Chipman Division/Rhodia

Table 6-9. Analysis of Wastewater*(67)

Component	Concentration (mg/l)
Phenol and cresol	10
Chlorophenols and chlorocresols	100
Chlorophenoxyacetic acids	100
Alcohols (primarily octyl)	1,000
Chlorides (as NaCl)	50,000
Sulfates (as Na_2SO_4)	8,000
Biochemical oxygen demand (BOD)	2,000
Chemical oxygen demand (COD)	3,600
Total solids	62,000
Suspended solids	10

---

*pH = 0.5

which operates at 980° C (1800° F) and insures complete destruction of all organics prior to discharge to the atmosphere. The effluent from the carbon column is neutralized with lime prior to discharge into municipal sewers.

6.3 EXPLOSIVES INDUSTRY

6.3.1 Military Explosives Industry

Table 6-10 summarizes the treatment/disposal technologies which are currently used or are being developed for the management of the "land-destined" hazardous wastes in the military explosives industry. The hazardous wastes of greatest importance are waste explosives, explosives-contaminated inerts (bulk metal and wooden materials, nonreusable boxes and containers, etc.), spent activated carbon from processing aqueous hazardous wastes, red water from TNT purification, organic solvents from propellant manufacture, and wastewaters containing dissolved and suspended RDX/HMX. Based on the technology classification system

Table 6-10. Treatment Disposal Technologies for Major Land-Destined Wastes in the Military Explosives Industry

Hazardous Waste	Technology Level		
	Typical (Level I)	Best Current (Level II)	Environmentally Acceptable (Level III)
Waste Explosives	Open burning	(Same as Level I)	Controlled Incineration: Rotary Kiln Fluidized Bed Closed Pit Soil Disposal: Composting Controlled Landfill Use in Commercial Blasting Agent Formulations
Explosives Contaminated Inert Wastes	"Flashing" (for equipment and noncombustibles); open burning (for combustibles)	(Same as Level I)	Controlled Incineration
Spent Activated Carbon	Open burning	(Same as Level I)	Controlled Incineration Thermal Regeneration Solvent Regeneration
Red Water	Concentration by evaporation and incineration of the concentrate	Concentration by evaporation and sale for paper company use	Fluidized bed reduction Tampella Process Red Water Acidification and Steam Stripping

discussed in Section 3, waste treatment/disposal technologies for the processing of major hazardous wastes in SIC 28922 are grouped into Levels I, II and III technologies, as shown in Table 6-10.

Waste Explosives

The most common method for the disposal of waste explosives is open burning. Waste material is spread over concrete pads and initiated (ignited) remotely. Major environmental drawbacks of the open burning techniques are: (1) the emission of significant quantities of air pollutants (particulates, NO_x, etc.), (2) the hazards associated with stockpiling a dangerous waste material, (3) the inefficient and uncontrollable nature of the operation, and (4) the potential for water pollution. Open burning is not considered environmentally adequate.

Controlled combustion for the disposal of explosives wastes has been successfully tested in pilot plant and prototype operations. Figure 6-5 presents a block flow diagram for explosive waste incineration. The two types of incinerator designs which have been tested are the rotary kiln and the catalytic fluidized bed. The test results and conclusions, which are summarized in a "Design Guide for Propellant and Explosive Waste Incineration"(68), indicate that, though both designs provide for safe operation with emissions meeting the regulatory standards, the fluidized bed system appears to be superior. Both techniques are considered environmentally adequate.

A third controlled combustion method which has been successfully tested in a prototype operation is the closed-pit batch incineration developed under AEC sponsorship.(69) Forced air circulation is used to decrease combustion temperature, improve performance and decrease NO_x formation. A gravel and dirt top is included in the design to provide for the removal of particulates and absorption of gaseous pollutants from the combustion gases.

A number of other promising concepts for explosives waste disposal are under consideration for pilot-plant testing and possible large-scale utilization. These include the use of scrap military explosives

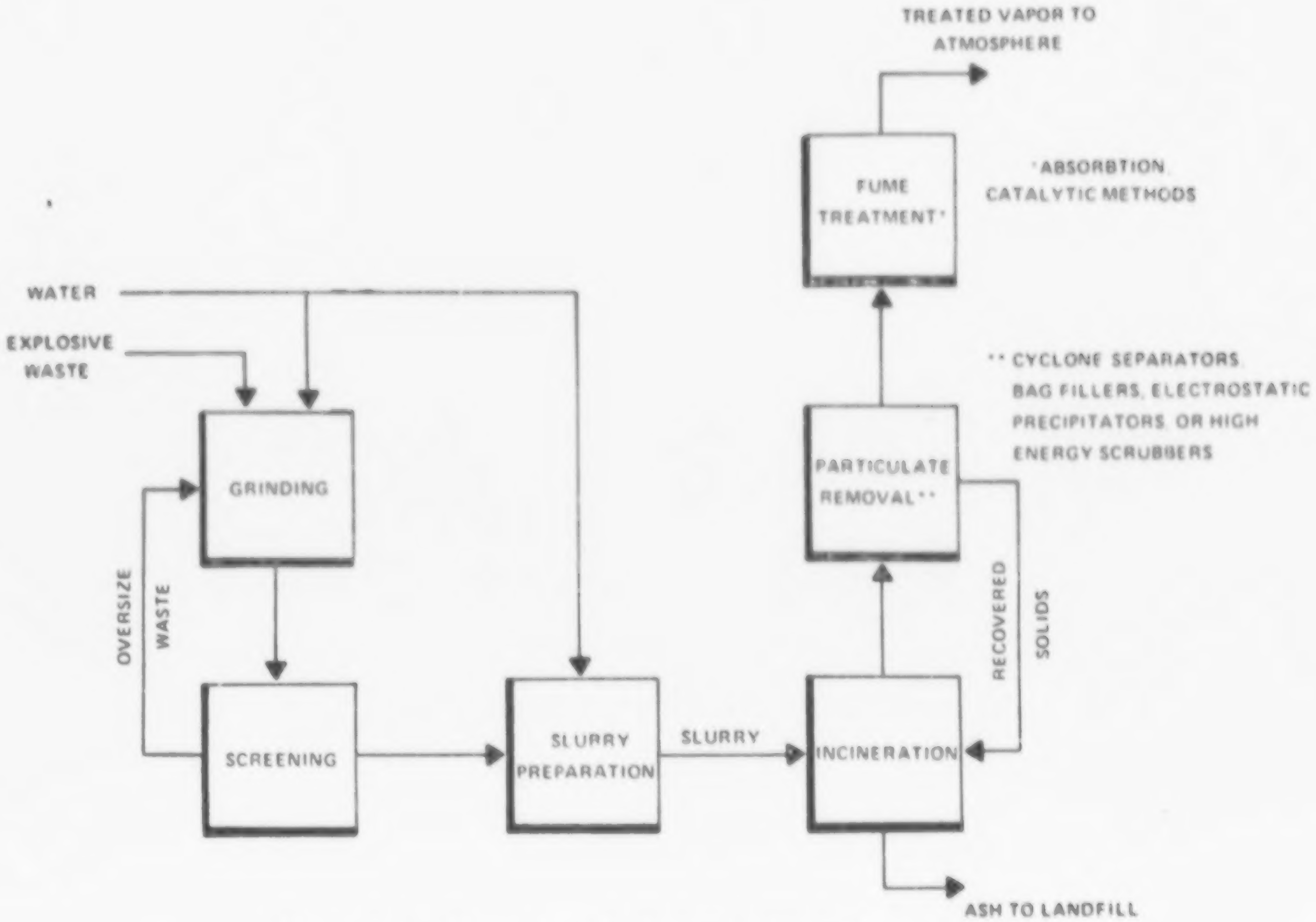
TREATED VAPOR TO ATMOSPHERE
FUME TREATMENT*
*ABSORBTION, CATALYTIC METHODS
WATER
EXPLOSIVE WASTE
** CYCLONE SEPARATORS, BAG FILLERS, ELECTROSTATIC PRECIPITATORS, OR HIGH ENERGY SCRUBBERS
GRINDING
PARTICULATE REMOVAL**
OVERSIZE WASTE
RECOVERED SOLIDS
SCREENING
SLURRY PREPARATION
SLURRY
INCINERATION
ASH TO LANDFILL

Figure 6-5. Disposal of Explosive Wastes by Incineration

in commercial blasting agent formulations, and controlled soil disposal to effect biodegradation.

The GOCO explosive plants do not use plastic/concrete encapsulation, leachate collection, or steel drums as safeguards in the disposal of waste explosives. The Level I technology, open burning, is also Level II technology; it is not considered environmentally adequate.

The Level III technologies for the disposal of waste explosives are all in the pilot plant stage. Required implementation times for complete Level III disposal systems are estimated as 2-3 years, (70) and the systems can be substituted for open burning at existing GOCO explosive plants. The sampling, testing and surveillance techniques required for adequate monitoring are available, and are within the capabilities of the GOCO facilities. The Level III technology systems will have no impact on water and noise pollution problems, and will decrease air pollution.

Explosive-Contaminated Inert Wastes

Open burning is used for the destruction of explosive-contaminated combustible materials such as: (1) large timbers, plywood and other materials of construction, and (2) nonreusable packaging and container items. Noncombustible contaminated materials such as equipment and metallic items, including process tanks, hoods, ducts and large unloaded ordnance items containing residual explosives, are thermally decontaminated by "flashing". Open burning and flashing are considered environmentally objectionable from the standpoint of generating air pollutants.

Incinerators have been developed for controlled combustion of contaminated inert wastes. A 270 kilogram (600 pound) per hour prototype unit has been constructed and successfully tested at Joliet Army Ammunition Plant. A schematic diagram of this prototype unit is shown in Figure 6-6. Monitoring of the stack effluent during the prototype testing has indicated compliance with applicable regulations. Based on the results of the operation at Joliet and of other engineering feasibility studies, a "Design Guide for Explosive Contaminated Inert Waste Incineration" (71) has been published.

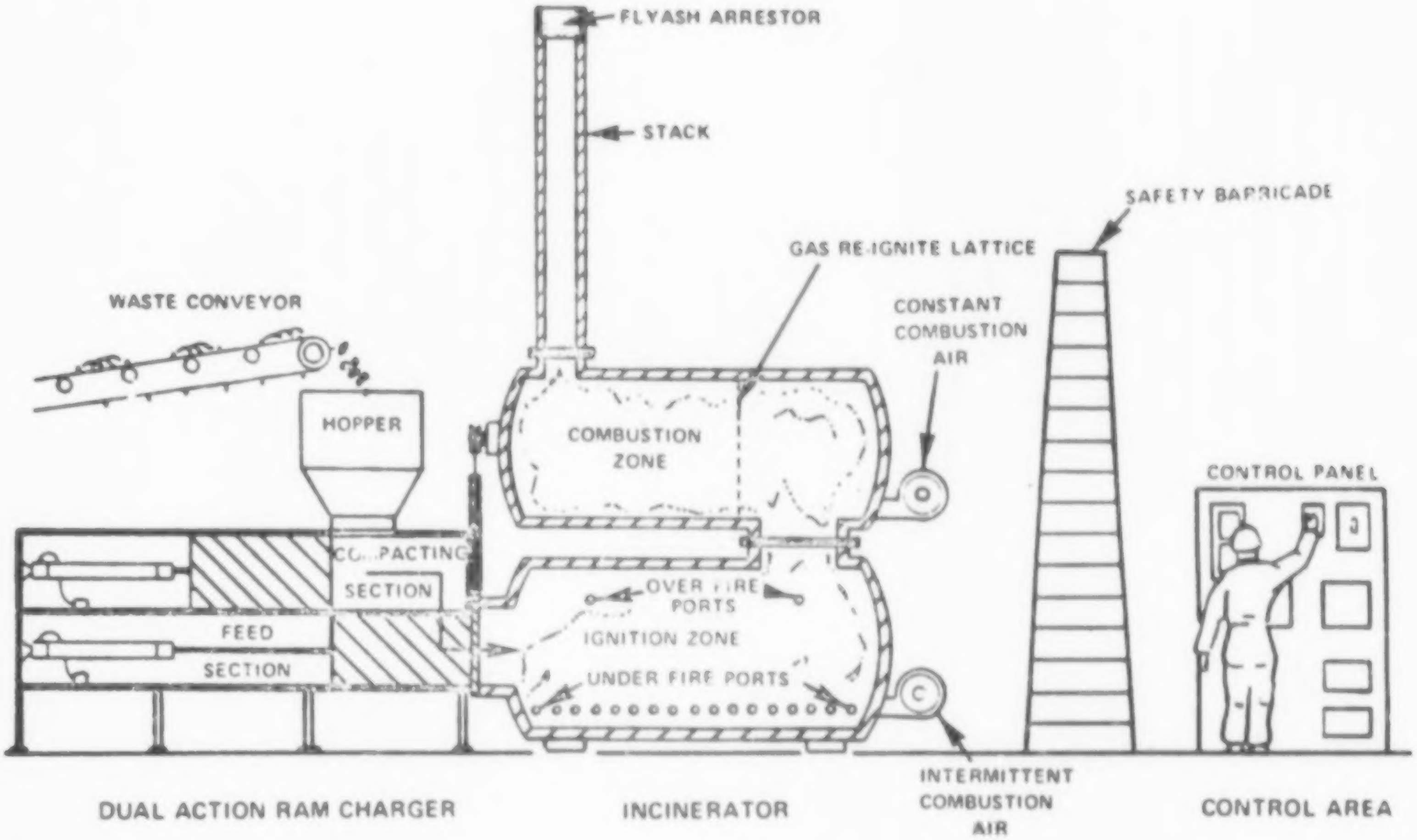
FLYASH ARRESTOR
STACK
SAFETY BARRICADE
GAS RE-IGNITE LATTICE
WASTE CONVEYOR
CONSTANT COMBUSTION AIR
HOPPER
COMBUSTION ZONE
CONTROL PANEL
COMPACTING SECTION
OVER FIRE PORTS
FEED SECTION
IGNITION ZONE
UNDER FIRE PORTS
INTERMITTENT COMBUSTION AIR
DUAL ACTION RAM CHARGER
INCINERATOR
CONTROL AREA

Figure 6.6. Joliet Army Ammunition Plant Contaminated Inert Waste Incinerator

Activated carbon adsorption has been shown to be an effective method for the removal of dissolved nitrobodies and a number of other explosive contaminants from wastewaters. Full-scale activated carbon adsorption units are in operation at a number of AAP's for the removal of nitrobodies from LAP waste waters. Activated carbon adsorption has also been considered for treatment of condensate from red water evaporation and for processing other aqueous wastes containing hazardous organics. Spent carbon is disposed of by open burning. Controlled combustion in an explosive waste incinerator is considered as a more desirable alternative. Regeneration of carbon for reuse is also being evaluated in laboratory studies. Two regeneration methods considered are thermal treatment in a fluidized bed, and elution with organic solvents.

The GOCO explosives plants do not use plastic/concrete encapsulation, leachate collection or steel drums as safeguards in the disposal of explosives-contaminated inert wastes.

The Level I and Level II technologies used for disposal of explosives-contaminated inert wastes and spent activated carbon wastes are identical; both Level I and Level II technologies are not considered environmentally adequate.

The Level III technologies for the disposal of explosives-contaminated inert wastes and spent activated carbon wastes are all in prototype or pilot plant stages. Required implementation times for complete Level III disposal systems are estimated as 3 to 5 years,(70) and the systems can be utilized by existing GOCO plants. The sampling, testing, and surveillance techniques required for adequate monitoring are available, and have been used in pilot and prototype units(70) and are described in the literature(60-63). The use of Level III disposal systems will have no impact on water and noise pollution problems and will decrease water pollution.

Red Water

The purification of crude TNT by neutralization with soda ash and washing with sellite (a solution of sodium sulfite) results in the generation of an alkaline red colored aqueous waste containing TNT impurities (sodium salts of dinitrotoluenesulfonic acids) and other organic and inorganic salts. The red water from batch TNT production is considerably more dilute than that from the new continuous TNT lines (3 to 5 percent vs. 30 to 35 percent solids). Because of a very low current rate of TNT production, the quantity of red water generated at the TNT plants is relatively small and is "disposed" of through sale to kraft pulp mills. Because of the small market, this method of disposal is viewed as only a temporary solution, and other potential alternatives are under active consideration. In the past, the voluminous quantities of red water generated were disposed of by incineration. The red water was neutralized with sulfuric acid, concentrated by evaporation, and the concentrate was incinerated in a rotary kiln (Figure 6-7). Since the quantity of ash produced was significant (0.19 kilograms per kilogram of TNT manufactured) large piles of ash have accumulated at some TNT production sites. At one plant the ash has been disposed of by land burial.

Because of the environmental inadequacies of the disposal methods, a considerable amount of effort is directed toward developing methods for the utilization and recycle of red water ash. Three of the most promising methods under investigation are fluidized bed reduction, the Tampella Process, and red water acidification.

In fluidized bed reduction (Figure 6-8) the ash is ground and reacted with carbon monoxide which also serves to fluidize the solids. Carbon monoxide is generated by reacting coke with carbon dioxide. The process produces sodium carbonate and H_2S which can be used (after conversion of H_2S to SO_2) to produce sellite solution for recycling. The fluidized bed reduction process has been evaluated in laboratory bench-scale tests.

In the Tampella Process, pulverized coal is added to the concentrated red water and the mixture is incinerated to produce a sodium carbonate smelt plus gaseous hydrogen sulfide; these are used to produce sellite for recycling. This process has been tested in pilot-plant studies.

In red water acidification, the wastewater pH is lowered by the addition of acid. Steam is then added to convert the nitrotoluene sulfonates in the red water to such useful compounds as diaminotoluene and dinitrotoluene. The red water acidification process is in the laboratory bench-scale evaluation stage.

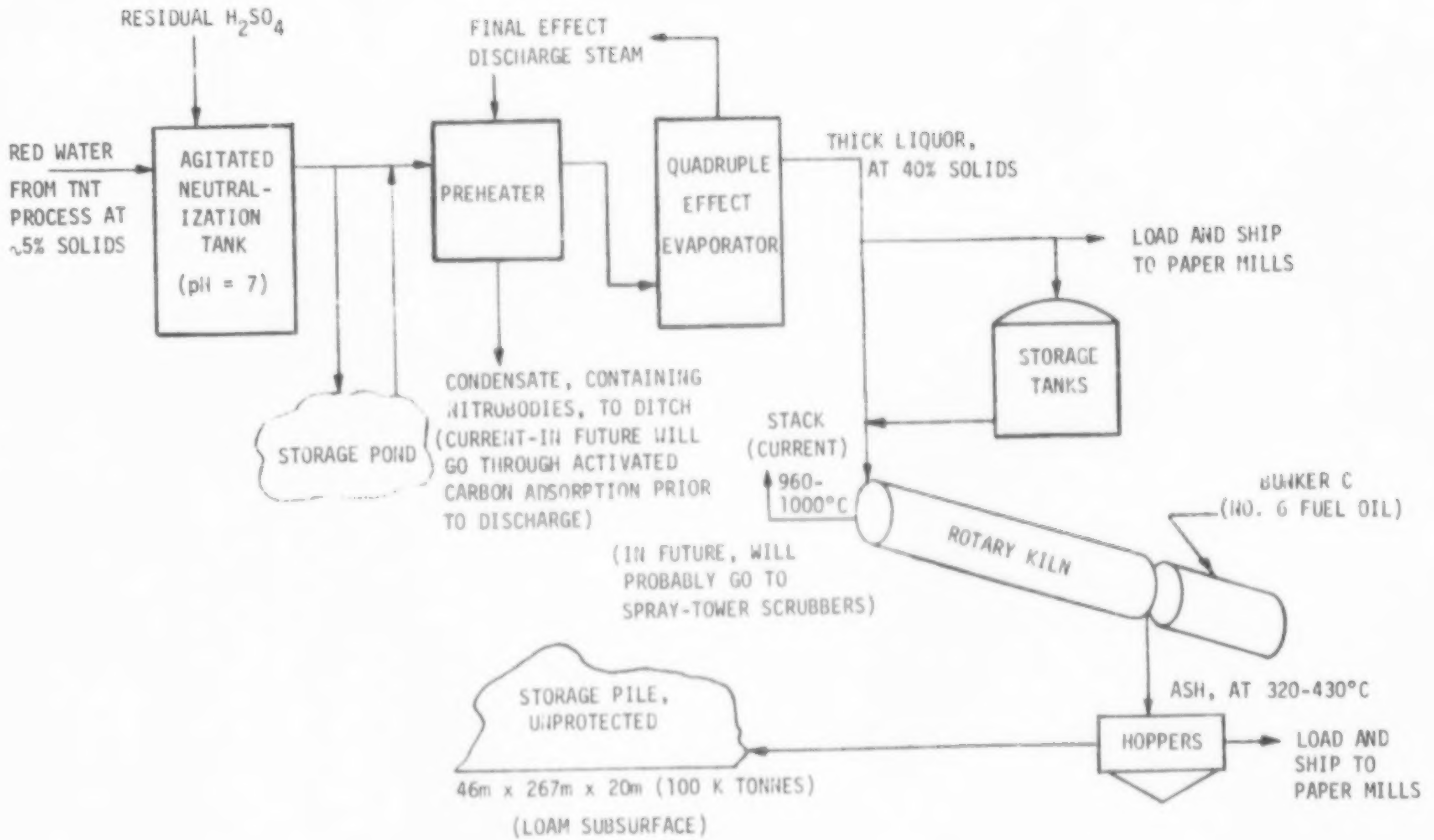
RESIDUAL H_2SO_4
RED WATER
FROM TNT
PROCESS AT
~5% SOLIDS
AGITATED
NEUTRAL-
IZATION
TANK
(pH = 7)
STORAGE POND
FINAL EFFECT
DISCHARGE STEAM
PREHEATER
CONDENSATE, CONTAINING
NITROBODIES, TO DITCH
(CURRENT-IN FUTURE WILL
GO THROUGH ACTIVATED
CARBON ADSORPTION PRIOR
TO DISCHARGE)
QUADRUPLE
EFFECT
EVAPORATOR
THICK LIQUOR,
AT 40% SOLIDS
LOAD AND SHIP
TO PAPER MILLS
STORAGE
TANKS
STACK
(CURRENT)
960-
1000°C
(IN FUTURE, WILL
PROBABLY GO TO
SPRAY-TOWER SCRUBBERS)
ROTARY KILN
BUNKER C
(NO. 6 FUEL OIL)
ASH, AT 320-430°C
HOPPERS
LOAD AND
SHIP TO
PAPER MILLS
STORAGE PILE,
UNPROTECTED
46m x 267m x 20m (100 K TONNES)
(LOAM SUBSURFACE)

Figure 6-7. Red Water Waste Disposal Process (Joliet AAP)

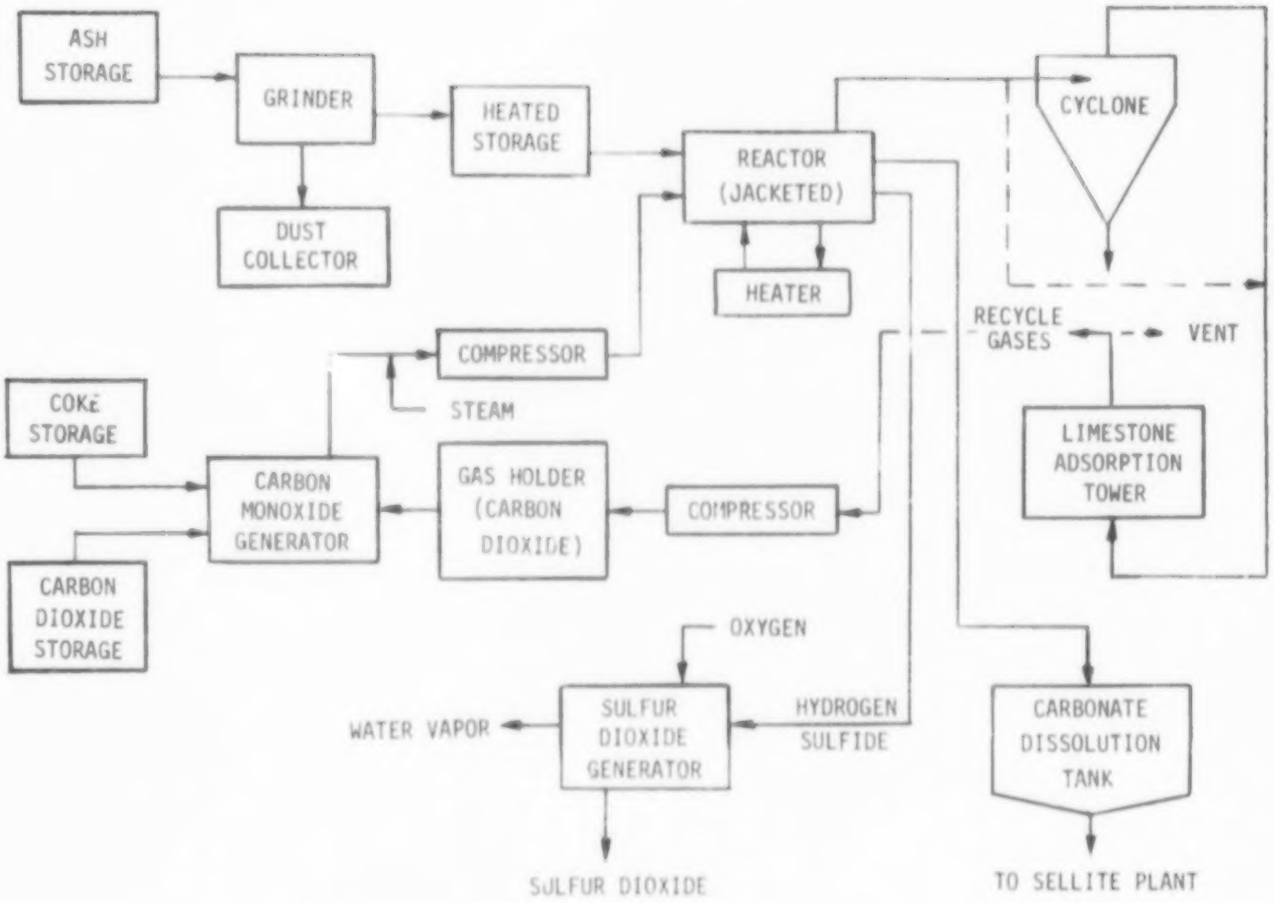
ASH STORAGE
GRINDER
DUST COLLECTOR
HEATED STORAGE
REACTOR (JACKETED)
HEATER
CYCLONE
RECYCLE GASES
VENT
LIMESTONE ADSORPTION TOWER
COKE STORAGE
CARBON DIOXIDE STORAGE
CARBON MONOXIDE GENERATOR
COMPRESSOR
STEAM
GAS HOLDER (CARBON DIOXIDE)
COMPRESSOR
OXYGEN
SULFUR DIOXIDE GENERATOR
HYDROGEN SULFIDE
WATER VAPOR
SULFUR DIOXIDE
CARBONATE DISSOLUTION TANK
TO SELLITE PLANT

Figure 6-8. Fluidized Bed Concept for Utilization and Recycling of Red Water Ash

In addition to the red water treatment/disposal technologies discussed above, a number of other approaches have been investigated to reduce wastewater volume and strength. Conversion of the batch TNT lines to the new and more efficient continuous lines was discussed in Section 5.4.1.1. Low temperature nitration of toluene, which results in a higher yield of α-TNT and hence production of a smaller quantity of undesirable isomers, is another attractive possibility for reducing waste quantities. Full-scale testing of the low-temperature nitration concept underway at one of the AAP's in 1974 when a halt in production resulted in discontinuation of the experiment. Adequate data were not available on the low temperature nitration method in 1974 to permit process evaluation.

Plastic/concrete encapsulation, leachate collection, and steel drums were not used by the GOCO plants as safeguards in the disposal of red water wastes from TNT production.

The Level I technology (concentration by evaporation, followed by incineration and open storage of the ash) is not considered environmentally adequate. The Level II technology (concentration by evaporation, and sale of the concentrated liquor to paper companies) which is considered environmentally acceptable can be applied to only a small portion of the red water wastes because of the limited marketability. The Level III technologies listed in Table 6-10 are all in the pilot plant stage. Required implementation plans for Level III technologies are estimated at 5 to 8 years.(70) The Level III techniques can be used at existing GOCO TNT plants. The sampling, testing, and surveillance techniques required for adequate monitoring of the fluidized bed reduction, Tampella and red water acidification/steam stripping processes are available and are within the capabilities of the GOCO plants. The Level III techniques will have no impact on air and noise pollution problems, and will decrease water pollution problems.

6.3.2 Commercial Explosives Industry

Compared to the military explosives industry, for which an extensive volume of data are available on waste treatment technologies, very little data are available on the commercial explosives industry. Although in some instances the nature of the problems and the required abatement methodology are the same for both industries, the pollution control effort in the military explosives industry is significantly more advanced because of the greater emphasis on development and installation of pollution control techniques in Federal installations.

Based on a search of the published literature(2, 20, 72-74) and visits to eight plant sites, the following are identified as the land-related waste treatment/disposal technologies used in the commercial explosives industry: (1) open burning of scrap explosives and contaminated wastes, (2) chemical detoxification, (3) contract disposal, (4) sale of scrap explosives or product waste to vendors for reclamation/reuse, (5) deep well disposal, and (6) spray irrigation or lagooning. Based on the available data and the technology classification defined in Section 2.3, for the commercial explosives industry open burning of scrap explosives is considered Level I technology, and the sale of scrap explosives or product waste to vendors for reclamation or reuse, and spray irrigation or lagooning of the aqueous wastes are considered as Level II and III technologies.

Open burning, the Level I technology, is generally conducted under special state permits which specify under what conditions the material can be air burned. Burning is usually conducted on concrete pads or in open pits. One commercial plant which manufactures propellants for the Air Force has seven concrete pads, each of which can be loaded with a maximum of 110 kilograms of materials. Another facility utilizes 12 "burning pits" which can each be loaded with 270 to 320 kilograms of waste propellants as needed. Except for safety considerations, and unless stipulated otherwise in the permit, there is generally no limit on the quantity of wastes which can be disposed of by open burning.

One particular application of open burning is the "open-top" incinerator developed by Du Pont (74), which is used at one of the plants visited for the disposal of nitrocellulose wastes. Wood is added to the wet nitrocellulose as fuel. The principal feature of the open-top incinerator is the admission of air for burning through closely spaced, high-velocity nozzles. The advantages claimed for this design include: (1) high flame temperature and turbulence which result in more complete combustion, (2) simplicity of loading and cleaning, and (3) lower maintenance cost than the conventional incinerators.

Chemical treatment with an alkali such as lime or limestone is used in some facilities for the deactivation of explosive-containing sludges such as those from the production of nitroglycerin and smokeless powder. One plant disposes of the treated sludge by discharge into a lagoon which overflows into a nearby river.

Concentrated acid wastes from manufacturing operations are usually either purified on-site and reused or sold to outside companies for reuse. At one nitroglycerin production site, the spent HNO_3/H_2SO_4 acid is denitrified by treatment with steam and the product sulfuric acid (30 percent acid content) is discharged to a temporary storage lagoon prior to sale to an outside acid supplier. The nitric acid contained in the steam effluent is not recovered and is discharged to the atmosphere. The quantity of nitric acid discharged to air at this site is estimated at 200 metric tons/year.

In the Level II and III technology used at one facility in northern California, the process wastewater is neutralized and disposed of on "percolation" land. Shallow and deep test wells are provided for monitoring the subsurface waste movement. Some of the waste at this facility has also been taken to a Class 1* disposal site. A deep well facility was constructed at this site for future waste injection into subsurface formations between 298 and 427 meters (980 and 1400 feet). The well is expected to operate under a well head pressure of less than 480 kilonewtons per square meter (55 pounds per square inch). In the event of well plugging, malfunction of the pH adjustment system or other contingency, the wastewater is to be diverted to a cement-lined basin which has a 15-day hold-up capacity.

In connection with a study of water pollution control in the commercial explosives industry, Patterson and Minear (75) visited a number of commercial explosives-manufacturing sites and found several applications of waste management by land irrigation and by storage in evaporation lagoons. These Level II and III methods of land treatment or disposal appear especially attractive for use by on-site explosive formulators and by plants located in arid and semi-arid regions. Land disposal data reported by Patterson and Minear (75) are summarized in Table 6-11.

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* See Appendix B for definition of "Class 1 disposal site".

Table 6-11. Use of Spray Irrigation and Evaporation Lagoons for Waste Disposal(75) in the Commercial Explosives Industry

Site Designation	General Location	Nature of Production Operation	Waste Pretreatment	Disposal Method and Site Characteristics
A	An arid region	Complex production facility producing ANFO, dynamites, various intermediates and specialty products	Sedimentation and oil skimming	Spray irrigation on a 48 K(m)^2 pasture of bermuda grass. Application rate 0.11 liter/[min.m^2]. Site used to graze cattle. Expansion of the irrigation area to additional 80-160,000 m^2 underway.
B	Upper Midwest	Complex production facility	Activated sludge and lagooning	Spray irrigation at a rate of 4.4 × 10^{-4} liter/[min.m^2]. Only about half of the waste percolates into the ground; the remainder appears as surface runoff.
C	Southeast	On-site small water gel formulation	None	Flow very small (95-114 liter/day). It is collected in a tank truck, and as necessary, sprayed onto an abandoned mine overburden disposal site on plant property.
D	An arid region	Complex production facility	None	Only waste streams from clean-up of ANFO-blasting equipment and NG neutralization disposed of by storage in evaporation/percolation lagoon.
E	Northern Midwest	On-site facility	None	All waste waters (17,600 liter/day in winter, 73,300 liter/day in summer) discharged to a natural basin, most of [illegible] by percolation.
F	Central Southeast	On-site water gel formulator	None	All process waste waters (3.8 liter/min) discharged to a lagoon having a capacity of 26,500m^3.

The commercial explosives industry does not use plastic/concrete encapsulation or leachate collection as safeguards in the disposal of its land-destined process wastes. There is insufficient data on which to base an estimate of the use of steel drums as safeguards in process waste disposal.

The Level I technology (open burning) is not considered environmentally adequate because of the factors cited in Section 6.3.1 for the use of this technique. The Level II and Level III treatment and disposal technologies employed by the commercial explosives plants are considered environmentally adequate. The Level III technologies of the military explosives industry, described in Section 6.3.1, are suitable for application to the disposal of the process wastes of the commercial explosives industry.

The sale of scrap explosives or product waste to vendors for sale and reuse and the military industry's Level III disposal technologies can be used at existing commercial explosives industry plants. The estimated required times for the implementation are from 5 to 8 years. The Level III technologies will decrease air and water pollution, and will have no effect on noise pollution problems. The sampling, testing, and surveillance techniques required for adequate monitoring are available and are within the plants' capabilities.

7. COST ANALYSIS

Because of the similarities in the treatment/disposal technologies used for management of wastes from the organic chemicals and pesticides industries and because of differences between these technologies and those employed in the explosives industries, the cost analysis in this section is presented in two separate subsections. Section 7.1 presents the cost data for treatment/disposal of 15 selected land-destined hazardous waste streams from the organic chemicals and pesticides* industries. The cost data pertaining to the explosives industry are presented in Section 7.2.

7.1 ORGANIC CHEMICALS AND PESTICIDES* INDUSTRIES

The hazardous waste streams and the three levels of treatment/disposal technologies for which cost estimates are made are listed in Table 6-4 and discussed in detail in Section 6.2. Except as noted in individual cases, the general basis for cost estimates and the criteria used are those listed in Table 7-1, and those contained in the discussions of the costs of individual treatment and disposal methods. All cost estimates have been adjusted to December 1973 dollars using the "CE Plant Cost Index" as reported each month in Chemical Engineering. The unit costs used for estimating capital and operating costs were obtained from the following sources: (1) direct contact with the industry, (2) published literature,(74,76-79) and (3) technical discussions with equipment manufacturers. The estimated capital cost was depreciated over the estimated service life of the equipment system using the straight-line depreciation approach. In cases where the land area devoted to on-site waste processing/disposal was appreciably large, the land value was considered as a capital cost item. For "off-site" land disposal,

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*Since the results of this study (as presented in Table 5-18) indicate that the hazardous waste tonnages discharged to land by the technical organic pest control chemicals product group (SIC 28694) were many times higher than the quantities of hazardous wastes discharged to land by the pesticides preparations and formulations industry (SIC 2879), the treatment and disposal cost analyses performed for the pesticides industries dealt exclusively with the practices of SIC 28694.

Table 7-1. Bases and Criteria for Cost Estimation

Private debt financing assumed for treatment and disposal facilities investment.

Cost of capital = annual interest on investment = 10 percent.[1]

Depreciation - straight line over estimated life for initial cost less salvage value.[1]

Estimated life for equipment and systems:

- Lagoons - 25 years[2]
- Landfill/other mobile equipment - 5 years[2]
- Incinerators, air pollution abatement devices, landfill serviced life, etc., - 10 years[2]

Land value = $14,800/hectare[3]

Labor (includes supervision, fringe benefits, and overhead) = $7.50/hour[2]

Maintenance (labor and materials) = 6 percent of investment[2]

Chemical Engineering Plant Cost Index, December 1973 index value of 144.1 (1957-59 = 100)

Incineration at 125% of stoichiometric air requirements.[2]

Sodium hydroxide used at 110% of stoichiometric requirements in scrubbing acid gaseous wastes.[2]

Waste/supplies shipment for 420 km (250 mi)[2]

Unit Costs:

Industrial power	$0.02/kw hr[4]
Freight cost, 420 kg (250 mi)	$35.30/metric ton ($32/ton)[4]
Sodium hydroxide, 50% liquid, 76% Na_2O basis	$126/metric ton ($114/ton)[4]
Activated carbon	$0.66/metric kg ($0.30/lb)[4]
Fuel oil	$84/metric ton ($12/bbl)[4]
Clay	$8.85/metric ton ($8/ton)[4]
Steel drums, lined (0.21 m^3 or 55 gal capacity)	$15 each[4]
Steel drums, used (0.21 m^3 or 55 gal capacity)	$7.50 each[4]
Water	$7.93/k($m^3$) ($30/Mgal)[4]
Concrete	$26.20/$m^3$ ($20/cu. yd)[4]
Excavation-shallow	$0.89/$m^3$ ($0.68/cu. yd)[2]
Excavation-deep (landfill)	$2.60/$m^3$ ($1.98/cu. yd)[2]
Surface finishing (leaching)	$44/$m^2$ ($0.37/sq. yd)[2]

[1] Cost of capital and depreciation were those prevalent in December 1973 and used as a common basis for this series of studies.

[2] Estimated by TRW on the basis of information from private industry sources.

[3] Cost estimated by TRW on an experience basis for industrial land in the Texas Gulf Coast area in December 1973.

[4] Quotations obtained by TRW from various private industry sources.

the cost for land investment was assumed to be included in the contractor's fee for waste handling and disposal. The typical plant site was assumed to be in the Gulf Coast region of EPA Region VI since this area contains the greatest concentration of organic chemicals production plants (as indicated in Table 4-4). For this area, the capital cost of land used for on-site waste processing/disposal was assumed to be $14,800 per hectare ($6,000 per acre).

The techniques and costs of many of the landfill disposal operations servicing the organic chemicals and pesticides industries are very similar to the techniques and costs for solid waste disposal in sanitary landfills. Figure 7-1 presents some estimates for solid waste disposal in sanitary landfills as reported by Heaney and Keane in 1970.(80) The factors which affect landfill disposal costs for the organic chemicals and pesticides industries include the size of the operation, the value of the land, the type of wastes (i.e., hazardous versus nonhazardous), and location characteristics including on-site availability of cover material.

The costs of disposal by incineration are varied depending on the size of the operation, waste characteristics, type of incinerator, and emissions control requirements. Figure 7-2 gives some perspective of the

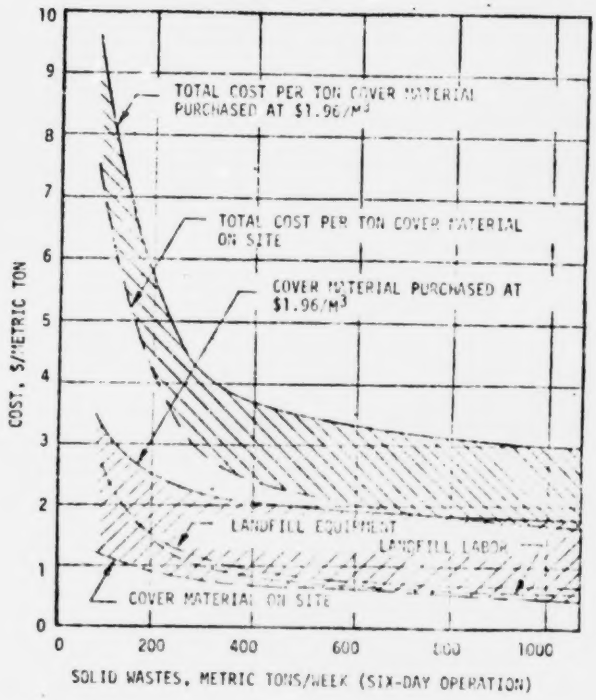

Figure 7-1. The Cost of Solid Waste Disposal in Sanitary Landfills(80)

(Note: The techniques and costs of landfill disposal operations for the organic chemicals and pesticides industries are very similar to those given for solid waste disposal in sanitary landfills.)

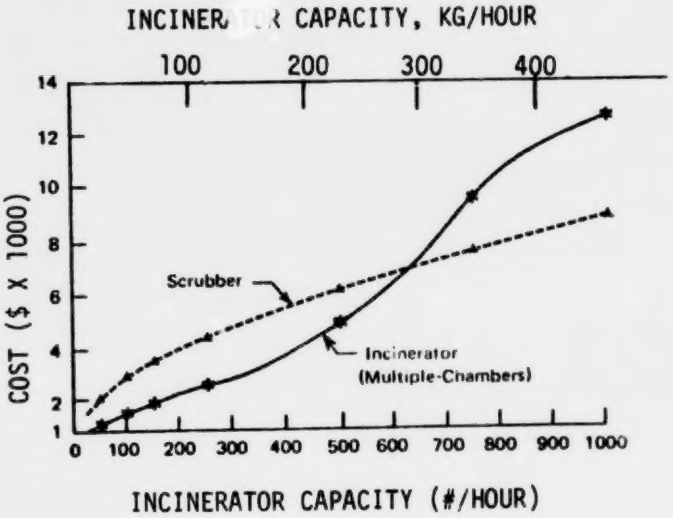

Figure 7-2. Cost of Small Scrubber-Equipped Incineration Systems in 1971(81)

capital costs for smaller size incinerator systems equipped with wet scrubbers for pollution control.(81) The capital investment for the new tar incinerator at Dow Chemical Midland facility (illustrated in Figure 6-2) was reportedly close to $2.25 million dollars. The operating costs for this unit and other incinerators which handle a total of 2460 cubic meters (650,000 gallons) of liquid waste tars and more than 700 drums of burnable chemicals each month are reported as $94,000 per month. The operating costs consist of $25,000 for labor (12 hourly operators, 1 foreman, and 1 superintendent), $20,000 for maintenance, $22,000 for utilities, $15,000 for general services (including landfill disposal costs), and $12,000 for miscellaneous items (materials, factory expense, technical projects, etc.).(49)

Because of the differences in the geological conditions in various regions of the country and in pretreatment requirements for different types of wastes, the capital investment for deep well injection varies at different locations and for different wastes. In 1971, the average cost for drilling and completing oil wells in the contiguous United States was $57.61 per meter of depth, with actual values ranging from a low of $13.97 in Nebraska to a high of $95.09 in one location in California.(65)(The Corresponding costs for waste injection wells should be somewhat higher.) A 1961 survey(65) indicated that the total costs of underground-waste-injection systems ranged from $30,000 (for a system without surface equipment for pretreatment of the waste) to $1,400,000, for one with elaborate equipment and a well 3660 meters (12,000 feet) deep. The average cost was $200,000. The operating cost for deep well injection is dependent on the pretreatment requirements and the operating pressure at the well head. The well pressures reported for existing facilities range from near vacuum to over 6900 kilonewtons per square meter (1000 pounds per square inch).

Estimates of the costs for new deep well disposal systems should be made on a case-by-case basis and require a detailed knowledge of the subsurface geology and physical and chemical characteristics of the waste. The following data are a statistical breakdown of costs for the example given in Section 6.2.3, including drilling and equipment costs for a "typical" disposal well completed by casing perforation at the disposal zone.(65)

Dimensions, meters (feet):

Depth of well	914 (3,000)
Surface casing, 2.67 cm (10-1/2 in.)	91 (300)
Injection casing, 17.8 cm (7 in.)	914 (3,000)
Tubing, 7.6 cm (3 in.)	91 (300)

Costs, dollars:

Drilling and completion costs	50,000
Tests	10,000
Engineering	20,000
Surface equipment	120,000
Total	200,000

The capital cost of an evaporation pond is determined primarily by the land value and the costs of excavation, construction of runoff diversion structures, and any additional equipment which is used for supplemental mixing and aeration. The operating costs are essentially those for pond maintenance, power consumption (in cases of supplemental mixing and aeration) and laboratory analysis for wastewater characterization and monitoring. Ferguson(66) reported on a preliminary design and cost analysis for an evaporation system handling an annual wastewater volume of 1,892 cubic meters (0.5 million gallons) from a pesticide formulating plant (18,120 metric tons or 40,000,000 pounds per year formulation rate). The data indicated that a system consisting of a pump, a surge tank (15,000 liter capacity), a concrete evaporation pad (4.57 meters wide, 9.14 meters long and 0.91 meters deep) with a roof, and an aeration pump, could probably be constructed with a capital investment of less than $10,000 and could be operated at an annual cost of close to $3,000. The reported(66) capital cost did not include the value of the land.

The cost of activated carbon adsorption is dependent on a large number of factors including wastewater characteristics, pretreatment needs, size of the operation, desired removal efficiency, and emission control requirements for the regeneration furnace. The quantity of carbon required for the treatment of biologically processed municipal wastewaters is in the 30 to 42 kilogram per 1000 cubic meter (250 to 350 pounds per million gallons) range. Higher carbon dosages would be required for raw municipal or industrial wastewaters which contain a significantly higher concentration or organics. For a 28,400 cubic meter per day (7.5 million gallons per day) advanced municipal waste treatment facility, the capital and operating costs of carbon adsorption have been reported as 0.57¢ and 0.87¢ per cubic meter of wastewater ($21.5 and $32.91 per million gallons), respectively.(82) The total capital expenditure for the pesticides industry activated carbon adsorption plant of the Chipman Division of Rhodia, Inc. (discussed in Section 6.2.3) is reported to be $300,000, and the operating cost is estimated at 9.4¢ per cubic meter (35.6¢/1000 gallons). The plant treats 568 cubic meter per day (150,000 gallons/day) of a phenolic wastewater.

A summary of cost estimates for the three levels of treatment/disposal technology for the 15 selected waste streams of the organic chemicals and pesticides industries is presented in Table 7-2. The cost items shown in this table include total investment cost, total annual operating cost (excluding energy cost), annual energy cost, and total disposal cost per metric ton of product and of hazardous waste. Table 7-3 presents a comparative listing of current costs (including transportation) for the disposal of land-destined organic chemical wastes, obtained from a private industry source which supplied information to TRW on a proprietary basis.

Table 7-2. Treatment and Disposal Technology Costs

Product		Waste Stream Description	Treatment and Disposal Technology – Descriptions				Costs			
Name	Metric Tons/ Year		Metric Tons/ Year	Level I	Level II	Level III		Level I	Level II	Level III
Perchloroethylene	35,000	Liquid heavy ends from perchloroethylene column	10,500	Deep well injection	Controlled incineration	Controlled incineration	Investment	$ 262,000	$1,080,000	Same as Level II
							Annual Cost			
							Capital	26,200	108,000	
							Operating*	74,000	430,700	
							Energy	67,600	64,200	
							Contractor	0	0	
							Total	167,800	602,900	
							Cost/Metric Ton			
							Of Waste	15.98	57.42	
							Of Product	4.79	17.23	
Nitrobenzene	20,000	Liquid distillation column heavy ends	50	On-site landfill	Controlled incineration	Controlled incineration	Investment	27,000	44,900	Same as Level II
							Annual Cost			
							Capital	2,700	4,500	
							Operating*	9,100	6,600	
							Energy	100	200	
							Contractor	0	0	
							Total	11,900	9,100	
							Cost/Metric Ton			
							Of Waste	238.00	182.00	
							Of Product	0.60	0.46	
Chloromethane Solvents	50,000	Solid tails from solvent recovery system	300	Contractor landfill	Controlled incineration	Controlled incineration	Investment	0	170,000	Same as Level II
							Annual Cost			
							Capital	0	17,000	
							Operating*	7,100[1]	95,900	
							Energy	0	1,100	
							Contractor	16,100	0	
							Total	23,200	114,000	
							Cost/Metric Ton			
							Of Waste	77.33	380.00	
							Of Product	0.46	2.28	
Epichlorohydrin	75,000	Liquid still bottoms heavy ends	3,975	On-site storage	Controlled incineration	Controlled incineration	Investment	984,000	934,000	
							Annual Cost			
							Capital	98,400	93,400	
							Operating*	102,900	753,900	
							Energy	100	2,400	
							Contractor	0	0	
							Total	201,400	849,700	
							Cost/Metric Ton			
							Of Waste	50.67	213.76	
							Of Product	2.69	11.33	

* Excluding energy

Table 7-2. Treatment and Disposal Technology Costs (Continued)

Product		Waste Stream Description	Treatment and Disposal Technology – Descriptions				Costs			
Name	Metric Tons/ year		Metric tons/ Year	Level I	Level II	Level III		Level I	Level II	Level III
Toluene Diisocyanate	27,500	Centrifuge residue sludge	588	On-site landfill	Controlled incineration	Controlled incineration	Investment	$ 28,500	$ 349,000	Same as Level II
							Annual Cost			
							Capital	2,900	34,900	
							Operating*	35,600	90,100	
							Energy	100	2,400	
							Contractor	0	0	
							Total	38,600	129,400	
							Cost/Metric Ton			
							Of Waste	66.00	214.63	
							Of Product	1.41	4.59	
Vinyl Chloride Monomer	100,000	Liquid heavy ends from still	3,800	Contractor incineration	Controlled incineration	Controlled incineration	Investment	0	473,000	Same as Level II
							Annual Cost			
							Capital	0	47,300	
							Operating*	0	738,700	
							Energy	0	1,600	
							Contractor	266,500	0	
							Total	266,500	787,600	
							Cost/Metric Ton			
							Of Waste	70.13	207.26	
							Of Product	2.66	7.88	
Methyl Methacrylate	55,000	Liquid heavy ends from methanol recovery	4,730	Uncontrolled incineration	Controlled incineration	Controlled incineration	Investment	114,500	134,800	Same as Level II
							Annual Cost			
							Capital	11,400	13,500	
							Operating*	81,100	84,500	
							Energy	5,700	5,900	
							Contractor	0	0	
							Total	98,300	103,900	
							Cost/Metric Ton			
							Of Waste	20.78	21.97	
							Of Product	1.79	1.89	
Acrylonitrile	80,000	Liquid heavy impurities – still bottoms	60	Uncontrolled incineration	Controlled incineration	Controlled incineration	Investment	44,100	55,600	Same as Level II
							Annual Cost			
							Capital	4,400	5,600	
							Operating*	14,800	24,500	
							Energy	200	300	
							Contractor	19,400	31,400	
							Total	38,800	61,800	
							Cost/Metric Ton			
							Of Waste	323.33	523.33	
							Of Product	0.24	0.38	

* Excluding energy

Table 7-2. Treatment and Disposal Technology Costs (Continued)

Product			Treatment and Disposal Technology - Descriptions				Costs			
Name	Metric Tons/Year	Waste Stream Description	Metric Tons/Year	Level I	Level II	Level III		Level I	Level II	Level III
Maleic anhydride	11,000	Sludge and residue (distillation column bottoms)	333	Landfill	Secured Landfill	Secured Landfill	Investment	$ 23,000	$ 30,700[2]	Same as Level II
							Annual Cost			
							Capital	2,300	3,100	
							Operating*	15,900	22,100	
							Energy	400	400	
							Contractor	0	0	
							Total	18,600	25,600	
							Cost/Metric Ton			
							Of Waste	55.86	76.86	
							Of Product	1.69	2.32	
Lead alkyls	60,000	Lead sludge from settling basin	30,000	Incineration with lead recovery as slag	Controlled incineration with lead recovery as slag	Controlled incineration with lead recovery as slag	Investment	513,100	613,900	Same as Level II
							Annual Cost			
							Capital	51,300	61,400	
							Operating*	269,300	285,400	
							Energy	228,500	228,800	
							Contractor	0	0	
							Total	549,100[3]	575,600[3]	
							Cost/Metric Ton			
							Of Waste	18.30[3]	19.19[3]	
							Of Product	9.15[3]	9.59[3]	
Aldrin	4,500	Area and equipment	289,000	Lined Pond	Lined Pond	Lined Pond	Investment	3,614,000	Same as Level I	Same as Level I
							Annual Cost			
							Capital	361,400		
							Operating*	256,100		
							Energy	200		
							Contractor	0		
							Total	617,700		
							Cost/Metric Ton			
							Of Waste	2.14		
							Of Product	137.27		
Atrazine	20,000	Scrubber spent alkali solution	224,600	Deepwell disposal	Deepwell disposal	Chemical detoxification by ozonization and deepwell disposal	Investment	425,200[4]	Same as Level I	779,200[4]
							Annual Cost			
							Capital	42,500		77,900
							Operating*	75,800		139,200
							Energy	8,600		34,300
							Contractor	0		0
							Total	126,900		252,400
							Cost/Metric Ton			
							Of Waste	0.57		1.12
							Of Product	6.35		12.62

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* Excluding energy

Table 7-2. Treatment and Disposal Technology Costs (Continued)

Product		Waste Stream Description	Treatment and Disposal Technology - Descriptions				Costs			
Name	Metric Tons/Year		Metric Tons/Year	Level I	Level II	Level III		Level I	Level II	Level III
Trifluralin	10,000	Solid spent activated carbon	1,750	Storage in rubber-lined steel drums	Storage in concrete trenches	Thermal regeneration of carbon with air pollution emissions control	Investment Annual Cost Capital **Operating*** Energy Contractor Total Cost/Metric Ton Of Waste Of Product	$ 37,200 3,700 331,600 200 0 335,500 191.71 33.55	$ 34,400 3,400 29,500 1,000 0 33,900 19.37 3.39	$2,250,000 225,000 30,000 12,000 0 267,000[5] 152.57 26.70
Parathion	20,000	Sulfur sludge from chlorinator	2,300	Uncontrolled incineration	Secured landfill	Secured landfill	Investment Annual Cost Capital **Operating*** Energy Contractor Total Cost/Metric Ton Of Waste Of Product	130,700 13,100 83,300 2,900 0 99,300 43.17 4.97	38,500[6] 3,800 22,800 1,200 0 27,800 12.09 1.39	Same as Level II
Malathion	14,000	Filter cake (semi-solid)	1,826	Detoxification with NaOH & burial with NaOH in approved landfill	Detoxification with NaOH & burial with NaOH in approved landfill	Detoxification with NaOH & burial with NaOH in approved landfill	Investment Annual Cost Capital **Operating*** Energy Contractor Total Cost/Metric Ton Of Waste Of Product	34,300 3,400[4] 28,100 800 0 32,300 17.69 2.31	Same as Level I	Same as Level I

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[1] Drums

[2] Secured landfill, assumed to be lined with 0.61 meters of dense clay; the waste is mixed 1:1 with the excavated dirt.

[3] No by-product credit was taken for 4,500 metric tons per year of lead recovered as slag because no data was available on the price of lead slag.

[4] Pond lining assumed to be an asphalt lining.

[5] In Level III credit was taken for the regenerated carbon (5 percent recovery assumed).

[6] Secured landfill assumed to be lined with a 0.61 meter layer of dense clay; the waste is mixed 1:1 with excavated earth.

[7] 0.22 kilograms of NaOH added per 100 kilograms of waste: waste mixed 1:1 with the excavated dirt.

* Excluding energy

Table 7-3. Comparative Data — Current Costs of Chemical Waste Treatment and Disposal for a Typical Organic Chemical Plant

Disposal Practice	Cost/Metric Ton*
Contractor secured unlined landfill, drummed wastes	$49.60
Contractor off-site incineration, drummed wastes	$66.10
Contractor secured lined landfill, drummed wastes	$79.40
On-site lined landfill, drummed wastes	$20.00
On-site controlled incineration, components	$60.00

*Quantities above 4000 metric tons per year; includes transportation for off-site disposal.

The weighted averages* of the cost estimates given in Table 7-2 for Levels I,II and III treatment and disposal technology are as follows:

Level I:	$13.36/metric ton of waste (wet basis); $48.32/metric ton of waste (dry weight basis);
Level II:	$30.56/metric ton of waste (wet basis); $110.54/metric ton of waste (dry weight basis);
Level III:	$30.69/metric ton of waste (wet basis); $111.02/metric ton of waste (dry weight basis).

The costs of treatment and disposal of the selected waste streams from manufacture of the 15 commodities, calculated as percent of 1973 sales values from Reference 30, have weighted averages of 0.9 percent for Level I treatment and disposal technology, and 2.2 percent for Level II and III technologies. The total national cost projected for the use of Level I technology for treatment and disposal of the 2.19 million metric tons (dry basis) of land-destined wastes discharged by the organic chemicals and pesticides industries is approximately $106,000,000. The basis used for calculation of this figure is the weighted average estimate of $48.32 per metric ton of waste (dry weight basis) given above. The value of organic chemicals and pesticides sales in 1973 is estimated (based on extrapolation of the data of Reference 30) as approximately $21.4 billion.

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*Weighted in accordance with the quantity estimated as the national total discharge in 1973 of each of the 15 selected waste streams.

The general discussion which follows is concerned with the sources of the major changes which can occur in the costs estimated for the applications of treatment and disposal technology to the industry subcategories shown in Figure 7-2. The discussion will include the effects of the conditions causing the major cost changes, and how these major cost changes may be estimated.

There are 13 different major types of treatment and disposal methods associated with the 15 industry subcategories and the three technology levels shown in Table 7-2. These 13 disposal methods and the major factors which affect the treatment and disposal costs for their application to the industry subcategories are shown in Table 7-4. As indicated in Table 7-4, the factors with major cost impact vary with the nature of the industry, the nature of the waste stream, and the technology used. These major factors (each of which is not necessarily applicable in all cases) include:

> Pretreatment requirements, site subsurface geology, waste stream discharge rate, emission control requirements, cost of land, availability/cost of cover material, transportation distances, contractor capital and operating costs, cost of drums, and cost of tanks.

The above factors are those which must be considered in estimating disposal costs for other plants and locations from the costs shown in Table 7-2 for specific waste treatment and disposal technology applications to typical plants located in the Gulf Coast area. For each treatment/disposal method, the effect of these factors may be estimated as follows:

1) The extent and nature of pretreatment required prior to final disposal of a waste is dependent on the waste characteristics, ultimate disposal method (e.g., incineration, deep well injection, landfilling, etc.) and applicable environmental regulations. The impact of differences in pretreatment is to change capital outlay,* and to change costs per metric ton of waste as a function of

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*Capital outlay, as used throughout this discussion, is synonymous with investment, as used in Figure 4-2.

Table 7-4. Major Factors Affecting Treatment and Disposal Costs at Typical Plants

Treatment and Disposal Method	Applicable Industry Sub-categories	Applicable Technology Levels	Major Factors Affecting Costs
Deepwell injection	Perchloroethylene	I	Pretreatment requirements, site subsurface geology, waste stream discharge rate
	Atrazine	I, II	Pretreatment requirements, site subsurface geology, waste stream discharge rate
Detoxification and deepwell injection	Atrazine	III	Pretreatment requirements, site subsurface geology, waste stream discharge rate
Controlled incineration	Perchloroethylene	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Nitrobenzene	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Chloromethane solvents	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Epichlorohydrin	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Toluene diisocyanate	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Vinyl chloride monomer	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Methyl methacrylate	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Acrylonitrile	II, III	waste stream discharge rate, emission control requirements
Controlled incineration	Lead alkyls	II, III	waste stream discharge rate, emission control requirements
Uncontrolled incineration	Methyl methacrylate	I	waste stream discharge rate
Uncontrolled incineration	Acrylonitrile	I	waste stream discharge rate
Uncontrolled incineration	Lead alkyls	I	waste stream discharge rate
Uncontrolled incineration	Parathion	I	waste stream discharge rate
On-site landfill	Nitrobenzene	I	Cost of land, availability/cost of cover material, waste stream discharge rate
On-site landfill	Toluene diisocyanate	I	Cost of land, availability/cost of cover material, waste stream discharge rate
On-site landfill	Maleic anhydride	I	Cost of land, availability/cost of cover material, waste stream discharge rate
Secured landfill	Maleic anhydride	II, III	Cost of land, availability/cost of cover material, waste stream discharge rate, site geology
Secured landfill	Parathion	II, III	Cost of land, availability/cost of cover material, waste stream discharge rate, site geology
Secured landfill	Malathion	I, II, III	Cost of land, availability/cost of cover material, waste stream discharge rate, site geology
Contractor landfill	Chloromethane solvents	I	Transportation distances, contractor capital and operating costs, waste stream discharge rate, cost of discharge rate
Contractor incineration	Vinyl chloride monomer	I	Transportation distances, contractor capital and operating costs, waste stream discharge rate
Evaporation ponds (lined)	Aldrin	I, II, III	Cost of land, site geology, waste stream discharge rate
Storage on-site in lined drums	Trifluralin	I	Cost of drums, cost of land, waste stream discharge rate
Storage on-site in steel tanks	Epichlorohydrin	I	Cost of land, cost of tanks, waste stream discharge rate
Storage in concrete trenches	Trifluralin	II	Cost of land, site geology, waste stream discharge rate
Thermal regeneration	Trifluralin	III	waste stream discharge rate, emission control requirements

change in capital outlay. The change in capital outlay must be estimated based on engineering and cost studies. Changes in disposal costs per metric ton for the baseline typical plant size can be estimated by multiplying the factors for annual capital cost, depreciation, and maintenance (which total about 0.26)* by the change in capital outlay, and dividing the result by the baseline typical waste stream discharge rate.

2) For deep-well injection, in addition to its impact on pretreatment costs, differences in subsurface geology also affects well depth and hence drilling costs and operating energy costs. An individual site survey must be performed at each site to determine well depth and energy consumption requirements. The effect of changes in well depth may be estimated for the typical Gulf Coast site by multiplying the depth change in meters by $70. Changes in drilling cost for sites other than Gulf Coast will require individual estimation based on the survey; they range from $75 per meter to $125 per meter.(65) These revised costs will change capital outlay and disposal costs per metric ton of waste. The change in disposal costs per metric ton of waste due to changed capital outlay can be calculated in the same fashion as for pretreatment costs. The effect of operating energy requirement changes is to change energy costs. The changed energy costs can be calculated by determining change in pump horsepower required and assuming 60 percent pump efficiency.

3) The effect of waste stream discharge rate changes is to change capital outlay requirements from those shown for the typical plant. The new capital outlay may be estimated by multiplying the baseline typical plant capital outlay by the factor

$$\left(\frac{\text{New waste stream discharge rate}}{\text{Baseline typical plant waste stream discharge rate}}\right)^{0.6}$$

The effect of the changed capital outlay requirements on disposal cost per metric ton of waste may be approximated by multiplying the change in capital outlay by the factor 0.26, and dividing the result by the new waste stream discharge rate. These estimation procedures can be used for all of the noncontractor-performed on-site treatment/disposal methods.

4) Emission control requirements have a major impact on the costs of controlled incineration, and are dictated by local, state and Federal regulations. The costs shown for capital outlay, operating (excluding energy) and energy in Table 7-2 for controlled incineration are based on maximum equipment requirements. Changes must be estimated on a case-by-case basis.

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*10 percent cost of capital, 10-year straight line depreciation, and 6 percent maintenance.

5) Cost of land has its major impact on the capital outlay requirements for landfill, evaporation ponds, and on-site storage. The effect on change in costs per metric ton of waste is a factor of the change in capital outlay. The approximate change in capital outlay may be calculated by multiplying the total land in acres required for the disposal facility by the difference between new land cost figure per acre and $6,000.* The change in cost of disposal per metric ton of waste may be estimated by multiplying the factors for annual cost of capital and depreciation** (which total about 0.20) by the change in capital outlay, and dividing the product by the baseline typical plant waste stream discharge rate.

6) Availability/cost of cover material impact the cost of landfill disposal, and must be determined on an individual site basis. A rough rule of thumb is that change in cost of cover material per cubic meter is approximately equal to change in cost of disposal per metric ton of waste, based on sanitary landfill practice.(80)

7) Waste transportation distance changes from the 402 kilometers (250 miles) used as baseline have a direct impact on the costs of contractor disposal via incineration or landfill. The change in cost per metric ton of waste must be determined by individual rate quotation, based on actual location, actual transportation distances, and actual waste quantities to be hauled.

8) Contractor capital and operating costs have a direct impact on the rates quoted for contract disposal via landfill and incineration. The rates quoted are also dependent upon quantity of waste disposal per unit time and the term of the contract. Contractor quotations must be obtained on a case-by-case basis.

9) Site geology has a major impact on the cost of disposal in secured landfills, storage in concrete trenches and evaporation ponds. The cost of protection required, which is a major cost factor, is directly dependent upon distance to groundwater, subsurface geology, climate (including rainfall and evaporation rate), topography, and monitoring requirements. Estimation of changes in cost must be on a case-by-case basis, with individual site surveys. The impact is generally a change in capital outlay, which results in a change in cost per metric ton of waste. The change in cost per metric ton of waste may be estimated by the method used for estimating changes in costs for pretreatment requirements.

10) The effect of changes in the cost of drums is major on costs for the contract landfill disposal of chloromethane solvent wastes,

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* A land cost of $6000 per acre has been used in the cost estimates shown in Table 7-2 (See also page 7-2).

** The land is assumed non-usable for other purposes due to the hazardous character of the wastes.

and for on-site lined drum storage of trifluralin spent carbon wastes. Changes in cost of disposal per metric ton of waste may be estimated as follows:

> For chloromethane solvent wastes, change in cost per metric ton of waste is equal to approximately the new cost of drums minus \$7.50 times 3.1.*
>
> For trifluralin spent carbon wastes, change in cost per metric ton of waste is equal to approximately the new cost of drums minus \$15.00 times 11.8.**

11) Changes in the cost of the steel tanks used for on-site storage of epichlorohydrin still liquid residues have a major impact on the capital outlay, and are reflected in changes in cost per metric ton of waste. The change in capital outlay will have to be estimated on a case-by-case basis. The change in cost per metric ton of waste may be estimated by multiplying the change in capital outlay by factors covering the cost of capital (10 percent), depreciation (15-year straight line) and maintenance (3 percent).

7.2 EXPLOSIVES INDUSTRY

As indicated in Section 5 explosives and explosives-contaminated wastes are the major land-destined hazardous wastes in the explosives industry. Currently these wastes are disposed of by open burning. Major cost elements for disposal by open burning are land value, transportation cost and the cost of operation and maintenance.

In the military explosives industry, the burning grounds are located on military reservation property and as such are carried at no cost to the plant operating contractors. Most waste-generating facilities in the commercial explosives industry (especially the large number of on-site ammonium nitrate-fuel oil (ANFO) formulators) are located in areas where the land is relatively inexpensive and the value of the land accounts for a very small fraction of the total disposal cost. Table 7-5 lists the cost for open burning at a selected number of Army ammunition plants based on a 1973

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*Based on 320 kilograms of waste (dry basis) per drum,

$$\frac{1000\ \text{kg/metric ton}}{320\ \text{kg/drum}} = 3.1\left(\frac{\text{drum}}{\text{metric ton}}\right)$$

**Based on 85 kilograms of waste (dry basis) per drum,

$$\frac{1000\ \text{kg/metric ton}}{85\ \text{kg/drum}} = 11.8\left(\frac{\text{drum}}{\text{metric ton}}\right)$$

Table 7-5. Cost of Waste Disposal by Open Burning at Selected Army Ammunition Plants(58)

Location	\$/lb	\$/kg
Nebraska	0.1907	0.4204
Tennessee	0.0218	0.0481
Tennessee	0.012	0.0265
Tennessee	0.2555	0.5633
Illinois	0.0101	0.0223
Missouri	0.2909	0.6413
Louisiana	0.0264	0.0502
Iowa	0.0013	0.0029

survey.(58) The variations in the reported costs reflect the differences in the size of the operation and in the costs for operation, maintenance, and waste transportation.

As indicated in Section 6, open burning is not an environmentally acceptable method for the disposal of explosives and explosives-contaminated wastes. Controlled incineration which provides for safe disposal of wastes is being developed as an alternative to open burning. Pilot plant studies which were conducted have resulted in the development of auxiliary components and techniques for waste preparation, handling, and incineration. The fluidized bed being considered for full-scale utilization is currently in advanced development and an economic assessment of the system is underway.(70) Preliminary data from this economic evaluation were not available to TRW for use in this study.

Based on data for the prototype unit shown in Figure 6-6, studies have been made of capital costs of systems for the disposal of contaminated inert waste by incineration.(71) Table 7-6 presents a summary of the capital cost data for three incineration systems having capacities of 2,300, 5,900, and 11,800 kilograms per day. The capital cost breakdown for the 5,900 kilograms per day system is shown in Table 7-7. The breakdowns for the

Table 7-6. Explosive Contaminated Inert Waste Incineration(71)

Capital Cost Summary

Item	Facility Capacity (kg/day) 2,300	5,900	11,800
Arch. & Struct.	$153,300	$ 207,000	$ 237,700
Electrical	59,300	73,000	81,100
Mechanical	40,900	45,500	48,900
	$253,500	$ 325,500	$ 367,700
10% Contingency	25,350	32,550	36,770
	$278,850	$ 358,050	$ 404,470
8.5% Engr. Support	23,702	30,434	34,379
	$302,552	$ 388,484	$ 438,849
5% S&A	15,127	19,424	21,942
Sub Total	$317,679	$ 407,908	$ 460,791
Equipment	$304,400	$ 619,200	$ 746,700
8% Engr. & Plant Support	24,352	49,536	59,736
Sub Total	$328,752	$ 668,736	$ 806,436
Total	$646,431	$1,076,644	$1,267,227

Table 7-7. Estimated Construction Cost for an Explosive Contaminated Inert[71] Waste Incineration Facility (Capacity 5900 kg (13,000 lbs)/day)

Building or Item	Arch. or Stru./Civil	Elec.	Mech.	Equip.	Total
Control Building	18,100	13,800	8,200	45,000	85,100
Inert Waste Process Bldg.	78,600	26,300	12,900	106,300	224,100
Incinerator & Fuel System	6,000			320,000	326,000
Ash Removal & Storage Hopper	1,300			143,800	145,100
Ramps	45,000	11,000	*	4,100	60,100
Site:					
Grading	18,500				18,500
Roads & Parking Areas	18,800				18,800
Drainage	4,000				4,000
Water Supply & Hydrants			24,400		24,400
Sanitary	6,000				6,000
Fertilizing & Seeding	1,900				1,900
Electrical		11,300			11,300
Security Lighting		10,600			10,600
Security Fence	8,800				8,800
Total	207,000	73,000	45,500	619,200	944,700

* Cost of Fire Protection for Ramps is included in Inert Waste Process Bldg.

projected operating costs were not available. TRW estimates of total disposal costs* are $360 per metric ton of waste for the 2,300 kilogram per day incineration unit, $214 per metric ton of waste for the 5,900-kilograms per day incineration unit, and $133 per metric ton of waste for the 11,800-kilogram per day incineration unit.

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*Includes costs of capital, operating costs (excluding energy), and energy.

8. REFERENCES AND BIBLIOGRAPHY

REFERENCES

1. Ricci, L. J. Injection well's iffy future. Chemical Engineering, 81(16):58-60, August 5, 1974.

2. Ottinger, R. S. et al. Recommended methods of reduction, neutralization, recovery or disposal of hazardous waste, v. 3. Disposal process descriptions – ultimate disposal, incineration, and pyrolysis processes. Redondo Beach, California, TRW Systems. Report No. 21485-6013-TU-00, Contract No. 68-03-0089. Environmental Protection Agency. February 1, 1973. 303 p.

3. U.S. Tariff Commission (U.S. International Trade Commi-sion). Synthetic organic chemicals, United States production and sales. 1973 preliminary reports. Washington, U.S. Government Printing Office, 1974-5. (A series of 14 individual monograms each covering a separate group or organic chemicals).

4. Synthetic organic chemicals, United States production and sales, 1972. United States Tariff Commission. TC Publication 681. 1974. 260 p.

5. Agricultural chemicals, N.E.C., SIC 2879 – preliminary report 1972 census of manufacturers industry series. Department of Commerce, Bureau of the Census. MC72(P)-28G-4. February 1974. 7 p.

6. The number of manufacturing establishments reporting shipments in the product classes. Private communication to G. I. Gruber, TRW Systems. Department of Commerce, Social and Economic Statistics Administration, Bureau of the Census. February 20, 1975. 1 p.

7. Cooper, W., and E. S. Biles. Numerical list of manufactured products (new 1972 SIC basis) – 1972 Census of Manufacturers. Department of Commerce, Bureau of the Census. MC72-1.2. May 1973. 337 p.

8. Gum and wood chemicals, SIC 2861 – preliminary report 1972 census of manufacturers industry series. Department of Commerce, Bureau of the Census. MC72(P)-28F-1. January 1974. 6 p.

9. Cyclic crudes and intermediates, SIC 2865 – preliminary report 1972 census of manufacturers industry series. Department of Commerce, Bureau of the Census. MC72(P)-28F-2. January 1974. 7 p.

10. Industrial organic chemicals, N.E.C., SIC 2869 – preliminary report 1972 census of manufacturers industry series. Department of Commerce, Bureau of the Census. MC72(P)-28F-3. February 1974. 9 p.

11. 1974 Directory of chemical producers – United States of America. Menlo Park, California, Stanford Research Institute, Chemical Information Services. 1974. 1063 p.

12. Dun and Bradstreet directory. New York, Dun and Bradstreet, Inc. 1975.

13. Caswell, R. L., D. E. Johnson, and C. Fleck. Acceptable common names and chemical names for the ingredient statement on pesticide labels. Environmental Protection Agency, Pesticides Regulation Division. 2nd ed. June 1972. 243 p.

14. Explosives, SIC 2892 — preliminary report 1972, census of manufacturers industry series. Department of Commerce, Bureau of the Census. MC72(P)-28H-2. March 1974. 7 p.

15. Apparent consumption of industrial explosives and blasting agents in the United States, 1973. Mineral Industry Surveys, Department of the Interior, Bureau of Mines. Explosives Annual. July 23, 1974. 12 p.

16. Alcohol, Tobacco and Firearms Division of Internal Revenue Service. (U.S. Treasury Department.) Private Communication on Explosive Manufacturers to M. Ghassemi of TRW Systems. February 1975.

17. Eskelund, G. R. Pollution control from explosive production waste streams. Proceedings of Fourth Annual Symposium on Environmental Pollution, Sponsored by American Ordnance Association. EO-SP-73001. Edgewood Arsenal, Office of Technical Director. September 1973. 160 p.

18. U. S. Army Armament Command. Private Communications to G. I. Gruber. TRW Systems. January 15, 1975.

19. Austin, G. T. The industrially significant organic chemicals — part I. Chemical Engineering, 81(2):127-132. January 21, 1974.

20. Hedley, W. H., S. M. Mehta, C. M. Moscowitz, et. al. Potential pollutants from petrochemical processes — final report. Dayton, Monsanto Research Corporation, Dayton Laboratory. MRC-DA-406. Environmental Protection Agency, National Environmental Research Center. December 1973. 365 p.

21. Petrochemical Handbook Processes. Hydrocarbon processing, 52:(11):91-198, November 1973.

22. Private Communication, Plant and waste characterization matrix. Baton Rouge, Louisiana, Ethyl Corporation. October 4, 1974.

23. Berg, E. L. Industrial waste survey of Union Carbide's Institute plant. Institute, West Virginia. Union Carbide Corporation. v. 1 and 2. December 20, 1974.

24. Groggins, P. H. Unit processes in organic synthesis. New York, McGraw-Hill Book Company, Inc., 1952. 937 p.

25. Faith, W. L., D. B. Keyes and R. L. Clark. Industrial chemicals, Third ed. New York, John Wiley and Sons. 1965. 852 p.

26. Austin, G. T. Industrially significant organic chemicals – part VII. Chemical Engineering, 81(13):149-156, June 24, 1974.

27. Austin, G. T. Industrially significant organic chemicals – part III. Chemical Engineering, 81(6):87-92, March 18, 1974.

28. Private Communication, Plant charaterization and waste characterization matrices. Westport, Connecticut, Stauffer Chemical Co.

29. Austin, G. T. The industrially significant organic chemicals – part II. Chemical Engineering, 81(4):125-128, February 18, 1974.

30. Austin, G. T. Industrially significant organic chemicals – part V. Chemical Engineering, 81(9):143-150, April 29, 1974.

31. Mattern, R. V. Statement of R. V. Mattern, Shell's Deer Park manufacturing complex on ocean incineration. Shell's Deer Park Manufacturing. October 4, 1974. 33 p.

32 Clausen, J. Trip report to Lucidol Chemicals Organic Peroxide Plant at Genesco, New York. Redondo Beach, California, TRW Systems. December 2, 1974.

33. Mark, H. F., J. J. McKetta, D. F. Othmer, and A. Standen. Kirk-Othmer encyclopedia of chemical technology, 2d ed. New York. Interscience Publishers, John Wiley and Sons. 1965.

34. Elderfield, R. C. Heterocyclic compounds. University of Michigan. v 1. John Wiley and Sons.

35. Petrochemical Handbook Processes. Hydrocarbon processing, 50(11):115-125, November 1971.

36. Private Communication, Plant characterization matrix – task I. Institute, West Virginia, Union Carbide Corporation.

37. Weston, R. F. Major organic products segment of the organic chemicals manufacturing point source category. Philadelphia, Roy F. Weston Company. EPA-440/1-74-009-a. Environmental Protection Agency, Office of Water and Hazardous Materials. April 1974. 363 p.

38. Austin, G. T. Industrially significant organic chemicals – part VIII. Chemical Engineering, 81(15):107-116, July 22, 1974.

39. Jones, H. R. Environmental control in the organic and petrochemical industries. Park Ridge, New Jersey, Noyes Data Corporation. Pollution Control Review No. 3. 1971. 257 p.

40. Minor, P. S., Organic chemical industry's waste waters. Environmental Science and Technology, 8:620-625, July 1974.

41. Lawless, E. W., R. V. Rumker, and T. L. Ferguson. The pollution potential in pesticide manufacturing. Kansas City, Missouri, Midwest Research Institute. TS-00-712-04. Environmental Protection Agency, Office of Water Programs, Applied Technology Division. June 1972. 250 p.

42. Johnson, O. Pesticides '72. Chemical Week, 110(25):33-66, June 21, 1972.

43. Saxton, J. C., and M. Kramer. Industrial chemicals solid waste generation — the significance of process change, resource recovery, and improved disposal. Arlington, Virginia, International Research and Technology Corporation. PB-233464. Environmental Protection Agency, Office of Research and Monitoring. June 1974. 144 p.

44. Austin, G. T. Industrially significant organic chemicals — part IV. Chemical Engineering, 81(8):86-90, April 15, 1974.

45. Austin, G. T. Industrially significant organic chemicals — part VI. Chemical Engineering, 81(11):101-106, May 27, 1974.

46. Austin, G. T. Industrially significant organic chemicals — part IX. Chemical Engineering, 81(16):96-100, August 5, 1974.

47. Melnikov, N. N., F. A. Gunther, and J. D. Gunther. Chemistry of pesticides. New York, Springer-Verlag. 1971.

48. White-Stevens, R. Pesticides in the environment. Rutgers University, New Brunswick, New Jersey. v. 1. Part I. New York, Marcel Dekker Inc. 1971.

49. Waste control at Dow-Midland. Midland, Michigan, Dow Chemical Company, Waste Control Department. 1974.

50. Designation and determination of removability of hazardous substances from water. Federal Register, 39(164):30466-30471, August 22, 1974.

51. United California Bank. 1975 Forecast. Los Angeles, United California Bank, Research and Planning Division. 1974. 64 p.

52. Christensen, H. E., et al. The toxic substances list 1973 edition. Department of Health, Education and Welfare. Superintendent of Documents. Washington, U. S. Government Printing Office. June 1973. 1001 p.

53. Hann, F. W. Jr. and Jensen, P. A. Characteristics of hazardous material. 4 v. College Station, Texas, Environmental Engineering Division, Civil Engineering Department, Texas Agricultural and Mechanical University. 1974.

54. Beckmann, R. B. et al. (Evaluation Panel, Committee on Hazardous Materials, Division of Chemistry and Chemical Technology, National Research Council). Evaluation of the hazard of bulk water transportation of industrial chemicals. A tentative guide. 1970 ed. with additions to September 22, 1972. Report No. CG-D-63-74. Washington, National Research Council. Contract No. GC-11, 775-A, DOT-OS-00035, Task Order 13. U. S. Coast Guard. July, 1973. 55 p.

55. Collection of Chemagro product technical information sheets on insecticides, herbicides, and fungicides. Kansas City, Missouri. Baychem Corporation, Chemagro Division. March 1973. 20 p.

56. Gross, G. W. Private Communication — Data transmittal. Rock Island, Illinois, Department of the Army, USAMC Installations and Services Agency. February 10, 1975.

57. Institute of Makers of Explosives. Personal Communications to J. R. Denson. TRW Systems. 1972.

58. Department of the Army. Unpublished data, resource recovery information survey. Rock Island, Illinois, U. S. Army Materiel Command Installation and Service Agency. 1974.

59. Ghassemi, M. Preliminary report on an in-depth pollution survey at Joliet Army Ammunition Plant. Redondo Beach, California. TRW Systems. Contract No. 4-80102-XAG. August 1974.

60. 1971 Annual Book of ASTM Standards. Part 23. Water: atmospheric analysis. Committees D-19 on water; D-22 on sampling and analysis of atmospheres. Philadelphia, American Society for Testing and Materials, 1971. 936 p.

61. Flegal, C. A. et al. Procedures for process measurements — trace inorganic materials. Redondo Beach, California, TRW Systems. Report No. 2444-6017-RU-00, Contract No. 68-02-1393. Environmental Protection Agency, July 1975. 141 p.

62. Shih, C. C. et al. Thermal degradation of military standard pesticide formulations. Redondo Beach, California, TRW Systems. Report No. 24768, 6019-RU-00, Contract No. DADA 17-73-C-3132. U. S. Army Medical Research and Development Command. 20 March 1975. 287 p.

63. Protection of the environment. Federal Register, 36(247):24882-24889. December 23, 1971.

64. Farb, S. D., and S. D. Ward. An inventory of hazardous waste management facilities. Washington, Environmental Protection Agency. August 1974.

65. Donaldson, E. C., R. D. Thomas, and K. H. Johnston. Subsurface waste injection in the United States. Bartlesville Energy Research Center. Bartlesville, Oklahoma Information Circular 8636. I28.27:8636. Department of the Interior. 1974. 72 p.

66. Ferguson, T. L. Pollution control technology for pesticide formulators and packagers. Midwest Research Institute, under contract to National Agricultural Chemicals Association. Grant No. R-801577. Environmental Protection Agency, Office of Research and Monitoring, June 1974. 150 p.

67. Henshaw, T. B. Adsorption plant cuts phenols from effluent. Chemical Engineering, 78(10):48-49, May 31, 1971.

68. Santos, J. et al. Design guide for propellant and explosive waste incineration. Dover, New Jersey. Manufacturing Technology Directorate, Picatinny Arsenal. Technical Report 4577. October 1973.

69. Worley, R. D. Disposal of waste or excess high explosives. Progress Report. Amarillo, Texas, Mason and Hanger — Silas Mason Company, Inc. MHSMP-74-39. Atomic Energy Commission, Albuquerque Operations Office, July-September 1974. 21 p.

70. Development of methods to minimize environmental contamination — quarterly report. Dover, New Jersey, Picatinny Arsenal. MM & TE 54114, June 1-August 31, 1974. 142 p.

71. Santos, J. et al. Design guide for explosive-contaminated inert waste incineration. Dover, New Jersey, Manufacturing Technology Directorate, Picatinny Arsenal. Technical Report 4586. November 1973.

72. Patterson, J. W., R. A. Minear. Pollution control in the commercial explosives industry. Chicago, Illinois Institute of Technology. Grant No. R-800857. Environmental Protection Agency, Office of Research and Monitoring, January 1974. 62 p.

73. Ottinger, R. S., et al. Recommended methods of reduction, neutralization, recovery or disposal of hazardous waste. v. 8. National Disposal Site Candidate Waste Stream Constituent Profile — Propellants, Explosives, and Chemical Warfare Materials. Redondo Beach, California, TRW Systems. Report No. 21485-6013-RU-00 (Contract No. 68-03-0089) Environmental Protection Agency. February 1, 1973. 282 p.

74. Baum, B. and C. H. Parker. Solid waste disposal — incineration and landfill. v. 1. Ann Arbor, Ann Arbor Science Publishers, Inc. 1974.

75. Patterson, J. W. and R. A. Minear. Pollution control in the commercial explosives industry. Grant R-800857. Environmental Protection Agency. April 1974.

76. Blecker, H. G., and T. W. Cadman. Capital and operating costs of pollution control equipment modules – user guide. Silver Spring, Maryland, ICARUS Corporation. EPA-R5-73-023a. v. 1. Environmental Protection Agency, Office of Research and Development, July 1973. 255 p.

77. Blecker, H. G., and T. M. Nichols. Capital and operating costs of pollution control equipment modules – data manual. Silver Spring, Maryland, ICARUS Corporation. EPA-R5-73-023b. v. 2. Environmental Protection Agency, Office of Research and Development, July 1973. 183 p.

78. Guthrie, K. M. Capital cost estimating. Chemical Engineering, 76(6):114-142, March 24, 1969.

79. Alonsa, J. R. F. Estimating the costs of gas cleaning plants. Chemical Engineering, 79(25):86-96, December 13, 1971.

80. Heaney, F. L. and C. V. Keane. Solid waste disposal. San Francisco, American Association of Cost Engineers. 1970.

81. Cross, F. L. Handbook on incineration. Westport, Connecticut, Technomic Publishing Co., Inc., 1972.

82. Evans, D. R. and J. C. Wilson. Capital and operating costs – AWT. Journal of Water Pollution Control – Federal, 44:1-13, January 1972.

83. Guthrie, K. M. Process plant estimating evaluation and control. Solana Beach, California, Craftsman Book Company of America. 1974.

84. Popper, H. Modern cost-engineering techniques. Chemical Engineering Series. New York, McGraw-Hill Book Company. 1970.

85. Chilton, C. H. Cost engineering in the process industries. Chemical Engineering Series. New York, McGraw-Hill Book Company. 1960.

86. 1972 Farm chemicals handbook. Willoughby, Ohio, Meister Publishing Company, 1972. 424 p.

87. Neal, L. G. Overview report of pollution abatement project. Redondo Beach, California, TRW Systems. Report No. 96020-006. Picatinny Arsenal, January 1973. 120 p.

88. Occupational safety and health standards. Federal Register, 39(125):23540-23670, June 27, 1974.

89. Ottinger, R. S. et al. Recommended methods of reduction, neutralization, recovery or disposal of hazardous wastes, v. 14. Summary of Waste Origins, Forms, and Quantities. Redondo Beach, California, TRW Systems. Report No. 21485-6013-RU-00. (Contract No. 68-03-0089). Environmental Protection Agency. February 1, 1973.

90. Atkins, Patrick R. The pesticide manufacturing industry - current waste treatment and disposal practices. Environmental Protection Agency Water Pollution Control Research Series, Project No. 12020 FYE. Washington, U.S. Government Printing Office, January 1972. 185 p.

BIBLIOGRAPHY

Alternatives to the management of hazardous wastes at national disposal sites. Cambridge, Massachusetts, Arthur D. Little, Inc., C-74861, May 1973. 85 p.

Alternatives to the management of hazardous wastes at national disposal sites — appendices. Cambridge, Massachusetts, Arthur D. Little, Inc., May 1973. 235 p.

Assessment of industrial hazardous waste practices, inorganic chemical industry, draft final report. Springfield, Virginia, Versar Inc. Contract No. 68-01-2246. Environmental Protection Agency, Office of Solid Waste Management, October 21, 1974. 400 p.

Chemical Engineering Staff. Pesticides: present and future. *Chemical Engineering*, 76(7):133-140, April 7, 1969.

Chemical preparations, N. E. C., SIC 2899 — preliminary report 1972 census of manufacturers industry series. Department of Commerce, Bureau of the Census. MC72(P)-28H-5, March 1974. 9 p.

Connolly, E. M. Pesticides. Menlo Park, California. Stanford Research Institute. Report No. 483. January 1973. 25 p.

Department of Transportation. An index to the hazardous materials regulations. Title 49, Code of Federal Regulations, Parts 170-180. Washington, Office of Hazardous Materials. October 1, 1973. 81 p.

Edwards, C. A. Environmental pollution by pesticides. Harpenden, Hertfordshire, England, Rothamsted Experimental Station. 1973.

Eiserer, L. A. C. World environment directory. Silver Spring, Maryland, Business Publishers, Inc. Vol. 1. No. 1. Summer 1974. 508 p.

Fedoroff, B. T. Encyclopedia of exposives and related items. Dover, New Jersey, Picatinny Arsenal. AD 257189. v. 1, 2, and 3. 1960.

Final Report of the Joint AMC/NMC/AFLC/AFSC Commanders' Panel on Disposal Ashore of Ammunition. Washington, Department of the Navy, Joint panel on disposal ashore of ammunition. 3 v. March and August 1973. 240 p.

Finkelstein, H. Air pollution aspects of pesticides. Bethesda, Maryland, Litton Systems, Inc. PB-188091. National Air Pollution Control Administration, Department of Health, Education and Welfare. September 1969.

Frisbie, L. How chemagro 'cleans up' waste water. Farm Chemicals, October 1972. 2 p.

Gibbons, D. R. Chemistry industry outlook through the 1970's. Cambridge, Massachusetts, Arthur D. Little, Inc. R740101. ADL Service Program Report Summary. January 1974. 26 p.

Gretton, O. C., and E. S. Biles. 1967 Census of manufacturers — industry statistics, part 2, Department of Commerce, Bureau of the Census. v. II., January 1971. 1008 p.

Heckroth, C. W. Special Report: Ocean disposal — good or bad? Water and Wastes Engineering. p 32-38, October 1973.

Honea, F. I., J. L. Barnard, W. A. Bullerdiek, and T. K. Mehrhoff. Disposal of waste or excess high explosives — progress report. Amarillo, Texas, Mason and Hanger — Silas Mason Company, Inc. MHSMP-73-11. Atomic Energy Commission, Albuquerque Operations Office. January-March 1973. 31 p.

Honea, T. I., and T. K. Mehrhoff. Disposal of waste or excess high explosives — progress report. Amarillo, Texas, Mason and Hanger — Silas Mason Company, Inc. MHSMP-74-2. Atomic Energy Commission, Albuquerque Operations Office, October-December 1973. 37 p.

Lawless, E. W., T. L. Ferguson, and A. F. Meiners. Methods for disposal of spilled and unused pesticides. Kansas City, Missouri, Midwest Research Institute. Contract No. 68-02-0098. Environmental Protection Agency. Safe Disposal Practices. 335 p.

Lawless, E. W., T. F. Ferguson, A. F. Meiners, and A. C. Aspoas. Methods for disposal of spilled and unused pesticides. Kansas City, Missouri, Midwest Research Institute. EPA Project No. 15090 HGR, Contract No. 68-01-0098. Environmental Protection Agency, Office of Research and Monitoring. April 1972.

Listing of visits to company headquarters, production sites and disposal sites. Springfield, Virginia, Versar, Inc. Contract Report. Environmental Protection Agency. 1974. 15 p.

Marchitelli, T. T. Economic feasibility of munitions disposal by ocean dumping. Naval Ordnance Systems Command, Logistics Support Directorate. February 14, 1974. 61 p.

Mechtly, E. A. The international system of units – physical constants and conversion factors, second revision. University of Illinois. NASA SP-7012. Washington, National Aeronautics and Space Administration, Science and Technical Information Office, 1973. 21 p.

Morekas, S. Review of development documents; group II effluent limitations guidelines and standards of performance. Hazardous Waste Assessment, Hazardous Waste Management Division (AW-565). Environmental Protection Agency. May 24, 1974.

Morekas, S. Industrial hazardous waste practices studies. Hazardous Waste Assessment, HWMD (AW-565). August 20, 1974.

Ogle, G. Crown-Zellerback folder of trip notes. Redondo Beach, California. TRW Systems, September 16, 1974. 15 p.

Ogle, G. Shell Chemical Company folder of general notes. Redondo Beach, California. TRW Systems, August 26, 1974. 20 p.

Pesticides and Pesticide Containers. Federal Register, 39(85):15236-15241, May 1974.

Report to Congress, Disposal of hazardous wastes. Office of Solid Waste Management Programs. Washington, Superintendent of Documents, SW-115. U. S. Government Printing Office, 1974. 110 p.

Slover, E. E. Union Carbide chemical landfill institute, West Virginia. Prepublication copy 2. Charleston, West Virginia, Union Carbide Corporation, June 28, 1971. 79 p.

Swift, W. H., et al. Program for the management of hazardous wastes. Richland, Washington, Battelle Memorial Institute, Pacific Northwest Laboratories, Contract No. 68-01-0762. July 1973. 385 p.

The Form of hazardous waste materials, Northeast Region, and Gulf Coast Region. Wilmington, Delaware, Rollins Environmental Services. September 7, 1972. 52 p.

Versar off-site disposal processor questionnaire. Hazardous Waste Assessment. Springfield, Virginia, Versar, Inc. 3 p. 1974.

Worley, R. D. Disposal of waste or excess high explosives. Progress Report. Amarillo, Texas, Mason and Hanger – Silas Mason Company, Inc. MHSMP-74-31. Atomic Energy Commission, Albuquerque Operations Office, April-June 1974. 31 p.

Worley, R. D., T. K. Mehrhoff and J. E. Wichmann. Disposal of waste or excess high explosives — progress report. Amarillo, Texas, Mason and Hanger — Silas Mason Company, Inc. MHSMP-74-14. Atomic Energy Commision, Albuquerque Operations Office, January-March 1974. 37 p.

1972 Census of manufacturers. Washington, U. S. Department of Commerce, Bureau of Census. MC 72(P)-28F. January 1974.

1972 Census of Manufactures. Numerical list of manufactured products (new (1972) SIC Basis). U. S. Department of Commerce, Bureau of the Census. MC 72-1.2. May 1973.

APPENDIX A

METHODOLOGY DETAILS

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DATA ACQUISITION A-2

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DATA ACQUISITION

The data used in this study were acquired predominantly from the open literature, prior EPA studies, industry and government sources, and prior TRW studies. The trade associations (e.g., Manufacturing Chemists Association, Synthetic Organic Chemical Manufacturing Association, and the National Agricultural Chemicals Association) were extremely cooperative, but were unable, because of charter restrictions, to function as intermediaries to obtain "hard" data on production, waste discharge, and waste treatment from their member companies. The data acquisition methodology varied somewhat between industries; each industry will, therefore, be treated separately. Table A-1 lists companies and agencies which supplied information on production and/or waste disposal methods.

Organic Chemicals Industry

The information acquired for the organic chemicals industry formed the data base from which estimates were made of production rates, processes, waste quantities, waste components, waste stream destination, and waste hazard classification for the individual chemicals produced at each plant site. The data acquisition methodology was keyed to these objectives.

The open literature, including prior studies on hazardous wastes, hazardous spills, and hazardous materials, furnished a majority of the information used as the "hard" data basis for estimation. A substantial minority of the data base on processes, wastes, and waste disposal, however, was obtained from industry sources, via meetings with industry personnel at company headquarters and production sites, and via correspondence requesting specific data. The organic chemicals industry facilities for which data were obtained directly from industry sources are included in the listing of Table A-1. As noted earlier, production rate information was regarded as proprietary by most companies. In addition, company policy in some cases required proprietary information protection agreements before any data could be released for use in this study.

The United States Tariff Commission was an extremely valuable source of information for assignment of the synthetic organic chemicals to the proper Standard Industrial Classification, and for key production data. The Commission's "Synthetic Organic Chemicals — United States Production and Sales" annual report for 1972,(4) and preliminary annual reports for 1973(8-10)

Table A-1. Companies and Agencies Supplying Information on Production and/or Disposal

Plants

Aerojet Solid Propulsion Company, Sacramento, California

*Allied Chemical Corp., Frankford Plant, Philadelphia, Pennsylvania

*Allied Chemical Corp., Ironton, Ohio

Badger Army Ammunition Plant, Wisconsin

Baychem Corp., Chemagro Division, Kansas City, Missouri

Commercial Solvents Company, Trojan U.S. Powder Division, Tacoma, Washington

Crown Zellerbach, Chemical Products Division, Camas, Washington

Diamond Shamrock Corporation, Greens Bayou, Texas

Dow Chemical USA, Midland Division, Midland, Michigan

Dow Chemical USA, Texas Division, Freeport, Texas

*E. I. duPont de Nemours and Co., Chambers Works, Deepwater, New Jersey

Edgewood Arsenal, Maryland

Ethyl Corporation, North Baton Rouge, Louisiana

Georgia Pacific, Albany, Oregon

*B. F. Goodrich Chemical Co., Akron, Ohio

*B. F. Goodrich Chemical Co., Henry, Illinois

Hercules, Inc., Bacchus, Utah

Hercules, Inc., Kenvil, New Jersey

Hercules, Inc., Parlin, New Jersey

Holston Army Ammunition Plant, Kingsport, Tennessee

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*Covered by proprietary rights/trade secrets protection agreements.

Table A-1. Companies and Agencies Supplying Information on Production and/or Disposal (Continued)

Hooker Chemical and Plastics Corp., Niagara Falls, New York

*ICI United States Inc., Atlas Point, New Castle, Delaware

Joliet Army Ammunition Plant, Joliet, Illinois

*Eli Lilly and Co., Tippecanoe Laboratory, Lafayette, Indiana

*Monsanto Industrial Chemicals Co., Sauget, Illinois

*Monsanto Commercial Products Co., Anniston, Alabama

*Monsanto Commercial Products Co., Muscatine, Iowa

*The Naval Ammunition Depots and Naval Propellant Plants

Pennwalt Corp., Lucidol Division, Genesco, New York

Picatinny Arsenal, Dover, New Jersey

Radford Army Ammunition Plant, Radford, Virginia

Reichold Chemicals Inc., Pacific Northwest Division, Tacoma, Washington

Rhodia Inc., Chipman Division, Portland, Oregon

Rhodia Inc., Chipman Division, St. Joseph, Missouri

Rubicon Chemicals, Geismar, Louisiana

Shell Oil Company, Shell Chemical Co., Axis, Alabama

Standard Oil of California, Chevron Chemical Co., Richmond, California

Standard Oil of California, Chevron Chemical Co., South Plainfield, New Jersey

Standard Oil of California, Chevron Chemical Co., Orlando, Florida

Standard Oil of California, Chevron Chemical Co., Fort Madison, Iowa

Standard Oil of Indiana, Amoco Chemicals Corporation

Chocolate Bayou, Texas
Decatur, Alabama

Table A-1. Companies and Agencies Supplying Information on Production and/or Disposal (Continued)

Joliet, Illinois
Wood River, Illinois
Texas City, Texas

Stauffer Chemical Co., Louisville, Kentucky

Stauffer Chemical Co., Mt. Pleasant, Tennessee

Stauffer Chemical Co., Omaha, Nebraska

Tenneco Chemicals Inc., Long Beach, California

Thiokol Chemical Co., Wasatch Division, Brigham City, Utah

Union Carbide Corp., Institute, West Virginia

Volunteer Army Ammunition Plant, Tennessee

Off-site Disposal Contractor Facilities

County of San Diego Public Works Agency, San Diego, California

Environmental Protection Corp., Bakersfield, California

Fresno County Disposal Site, Fresno, California

Omar Industrial Pumping, Chula Vista, California covered national total statistics, where publishable, on United States production and sale of all synthetic organic chemicals and, with certain exception, identified the companies which manufactured each chemical. The Commission's reports do not, however, contain data on the amounts produced by each company, or on the plant sites at which the individual chemicals are manufactured.

The Bureau of Census "Preliminary Report — 1972 Census of Manufactures"(18) was the source of the total United States production data for gum and wood chemicals, and statistics on the number of establishments producing gum and wood chemicals.

To acquire the base from which to estimate the statistics on individual chemical production at each plant site, this study used the 1974 Directory of Chemical Producers — United States of America," Chemical Information Services, Stanford Research Institute,(11) other open literature sources, and some limited private industry input. The Directory indicated, under the pertinent company headings, the location of each organic chemical plant site, and the chemicals manufactured at the plant site. For many of the major commercial organic chemical commodities, plant production capacity estimates these capacity figures were available(11) and utilized.

Data used to furnish the base for estimates of waste quantities and components were obtained from the prior EPA studies and other literature sources cited as references throughout the body of this report, and from the industrial sources cited in Table 3-1. Most industrial companies producing organic chemicals do not monitor either the quantity of process wastes sent to land for disposal or the components of the process waste streams. In consequence, much of the information received on process waste from industrial sources represented "best estimates" based on old/partial data on the part of knowledgeable personnel responsible for production and/or environmental control — waste processing and disposal. Where the industrial sources provided information under the cover given by proprietary rights/trade secret protection agreements, use was in part restricted to serve as a check upon the estimates made.

The data covering typical hazardous waste processing and disposal practices were to a large extent obtained from the industry sources cited in Table A-1 and from the open literature.

The standard cost literature(75, 83-85) in conjunction with data from the prior EPA studies served as a basis for cost estimation. The indices reported periodically in Engineering News Record and Chemical Engineering were also employed as information sources.

Pesticides Industries

The pesticides industries, discussed in this study, include both the manufacture of technical organic pesticides*, normally included among the organic chemicals under Standard Industrial Classification 28694, and the manufacture of pesticide preparations and formulations – Standard Industrial Classification 2879. Data acquisition for SIC 28694 followed the methodolgy given above under Organic Chemicals Industry. Data acquisition for SIC 2879 was as follows.

The major comprehensive sources of industry-wide information on production for the pesticides preparations industry were the Bureau of the Census, and the Farm Chemicals Handbook.(86) The remaining production data were either considered proprietary (by the private industry sources involved), or presumed protected against disclosure by public law** (for material in the files of the EPA Pesticide Registration Division), or were so fragmented that their acquisition would involve much additional time and be too costly. Based on a preliminary evaluation of the relative importance of hazardous waste streams discharged to land disposal by the pesticide preparation portion of the industries, which indicated a relatively low tonnage, it was decided to acquire statistics sufficient to yield production estimates at the state level for the industry as a whole.

The Bureau of the Census furnished the information needed for these estimates. The "Preliminary Report, 1972 Census of Manufacturers, Industry Service, Agricultural Chemicals, N.E.C."(5) covered sufficient material statistics on quantities and values of preparations (formulations) shipped or manufactured to permit an estimate to be made of total quantity produced for the industry as a whole. A private communication from the Census Bureau(6) furnished data on the geographical distribution of the manufacturing establishments.

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*Bureau of the Census(7) terminology used at times in this text is "technical organic pest control chemicals."

**Federal Insecticide, Fungicide, and Rodenticide Act.

Information on characteristic pesticide preparation waste stream quantities, contents, and disposal practices was obtained from the industry sources listed in Table 3-1 and from prior EPA studies. Data acquisition for cost analysis followed the methodology employed for the organic chemical industry.

Explosives Industry

In general, the explosives industry has been treated as a two-segment industry (Sections 4.4 and 6.3): the military explosives industry which manufacture explosives for defense, and the commercial explosives industry which product explosives for use by the private sector of the economy.

The great majority of explosives produced for defense are manufactured at the Army ammunition plants. The United States Army Armament Command furnished detailed reports, or arranged meetings at the Army ammunition plants, to cover individual explosive production and hazardous waste data at each plant. The data furnished included cost information. Where information was missing, prior TRW studies of environmental pollution abatement activities at the Army ammunition plants furnished the basis for estimation. Additional detailed information was obtained from the plants manufacturing propellant for the Air Force, from the Naval ammunition depots load-assemble-pack operations, and from other defense activities.

Data acquisition for the privately operated sector of the industry, because of the paucity of the product and production information base, was on the basis of state-by-state statistics for explosive product groups. A survey by the Bureau of Mines(7) included statistics on the apparent consumption of industrial explosives and blasting agents. A private communication from the Alcohol, Tobacco and Firearms Bureau of the Treasury Department(16) provided the geographical location of all the private sector plants. Data from a prior TRW study,(87) and from the private sector companies listed in Table 3-1 was used as the primary basis for the remainder of the estimates made.

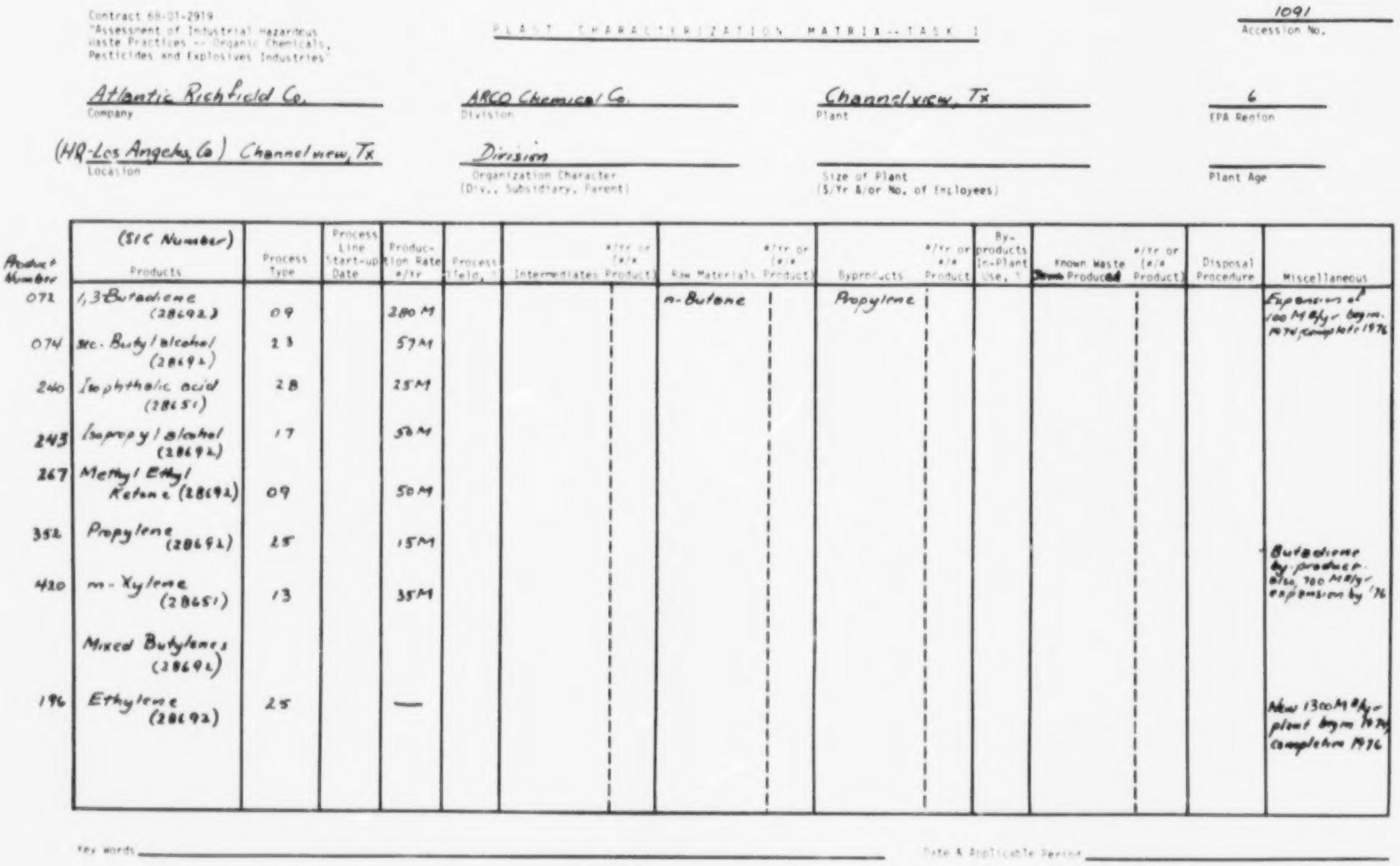
DATA COLLATION AND ANALYSIS

Plant characterization matrix forms (Figure A-1 is a specimen form) were developed for this study to collect and record production and process information extracted from the literature as well as statistics and descriptions obtained from industrial sources. Data forms of this type were completed for 899 plant sites for the organic chemicals industry. Based on the criteria given below 373 organic chemicals were included in the study. The criteria used in the study were to include:

1) Individual organic chemical compounds whose production in the United States was 10 million pounds per year or more.
2) Groups of closely related organic compounds for which production data were readily accessible, or for which group production was 10 million pounds per year or more.
3) Organic chemical compounds closely related to the compounds of (1) above.
4) Suspected carcinogens, 14 of which were not included under (1), (2), and (3) above.
5) Technical organic pesticides for which United States production was 1 million pounds per year or more.

A highly significant sample representing 90 percent of the tonnage produced in 1973 by the industry was obtained under these criteria.

The organic chemicals industry was divided into 12 five-digit Standard Industrial Classification product groupings for statistical summary purposes. For most of the organic chemicals, each entry made in the plant characterization matrices was then examined to determine what production data were missing. The portions of the total annual national production of each chemical not accounted for in the known production capacity entries were prorated (distributed equally) among the remaining companies listed as manufacturers for the chemicals in question, and further prorated (by the same method) among the individual company plant sites listed as production sites.



Contract 68-01-2919
"Assessment of Industrial Hazardous Waste Practices -- Organic Chemicals, Pesticides and Explosives Industries"

PLANT CHARACTERIZATION MATRIX--TASK I

1091
Accession No.

Company: Atlantic Richfield Co.
Division: ARCO Chemical Co.
Plant: Channelview, Tx
EPA Region: 6

Location: (HQ-Los Angeles, Ca) Channelview, Tx
Organization Character (Div., Subsidiary, Parent): Division
Size of Plant ($/Yr &/or No. of Employees):
Plant Age:

Product Number	(SIC Number) Products	Process Type	Process Line Start-up Date	Production Rate #/Yr	Process Yield, %	Intermediates	#/Yr or (#/# Product)	Raw Materials	#/Yr or (#/# Product)	Byproducts	#/Yr or #/# Product	By-products In-Plant Use, %	Known Waste Produced	#/Yr or (#/# Product)	Disposal Procedure	Miscellaneous
072	1,3 Butadiene (28692)	09		280 M				n-Butane		Propylene						Expansion of 100 M #/yr begin. 1974; complete 1976
074	sec-Butyl alcohol (28692)	23		57M												
240	Isophthalic acid (28651)	28		25M												
243	Isopropyl alcohol (28692)	17		50M												
267	Methyl Ethyl Ketone (28692)	09		50M												
352	Propylene (28692)	25		15M												Butadiene by-product. also, 700 M #/yr expansion by '76
420	m-Xylene (28651)	13		35M												
	Mixed Butylenes (28692)															
196	Ethylene (28692)	25		—												New 1300 M #/yr plant begun 1974; completion 1976

Key words:

Date & Applicable Period:

Figure A-1. Plant Characterization Matrix Form

Two organic chemical product groups (SIC's 28652 and 28653 – dyes and pigments, respectively) were divided into product categories for estimating production data, and for process analysis and statistical summaries. Seven categories of dyestuffs, on the basis of category production in excess of 10 million pounds per year, were considered to represent SIC 28652. The synthetic organic pigments product group (SIC 28653) included four major pigment categories for which production (with one exception) was more than 10 million pounds per year. The estimation of production rates for the dye and pigment categories was handled in a manner analogous to that cited for the bulk of the organic chemicals.

Technical organic pest control chemicals (SIC 28694) for which individual production figures were available were divided into 17 chemical groups for process and waste generation analysis.

A process description was written, using the data base assembled, to describe the manufacture of each criteria organic chemical, and to describe the manufacture of dyes, pigments and technical pesticides representative of each group. Each process description was then classified as one of the 31 process types used in this study, and the appropriate entry made in all of the pertinent plant characterization matrices.

For each plant characterization matrix, the production estimates for all organic chemicals in each five-digit SIC product group were summed. This yielded the figures descriptive of "plant size" for each of the individual five-digit SIC product groups manufactured at the plant site. A plant site could thus have several "plant size" ratings.

For each state, the production estimates of all organic chemicals in each five-digit SIC product group manufactured at plant sites within the state were added. The sums represented the annual production rates of each of the SIC's produced within the state.

No entries were made to cover "plant age" for the organic chemicals industry, since almost all of the industrial sources listed in Table A-1 had indicated that their production processes had been modified so frequently that start-up date was meaningless, technically. These statements were in accord with the extremely competitive character of the organic chemicals industry, and the rapidity of technical and process system advances in that industry.

The pesticides preparations and formulations industry production statistics presented on a state-by-state basis for the preparations industry as a whole were obtained by prorating the estimated total national production. Prorating was on the basis of the fraction of total establishments reported for each state by the Bureau of the Census.(5)

The detailed GOCO explosives industry data furnished by the United States Army Armament Command, supplemented by data from a prior TRW report(87) was used for the production statistical summaries. The statistical summaries of production on a state-by-state basis for the private sector of the explosives industry assumed that production in each state was equal to the consumption reported for the state by the Bureau of Mines.(15)

HAZARDOUS WASTES — IDENTIFICATION AND ESTIMATION

Criteria were developed to enable proper identification and estimation of hazardous wastes (See Table 3-1). The criteria divided waste streams into two major categories on the basis of the characteristics of their components — hazardous wastes and other wastes. Hazardous wastes were separated further into two classes — Moderately dangerous and highly dangerous.

The major bases used to assess the waste streams were:

- Potential to cause human death, injury, illness, or harm to wildlife/beneficial biota.*
- Possible paths for harmful entry into the environment, throughout the entire cycle of waste management.**

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*See Table 3-1 for the quantitative basis used to rate components of the waste streams.

**Based on consideration of the solubility, dispersibility, physical form and concentration of all components rated as hazardous by the methods shown in Figure A-2.

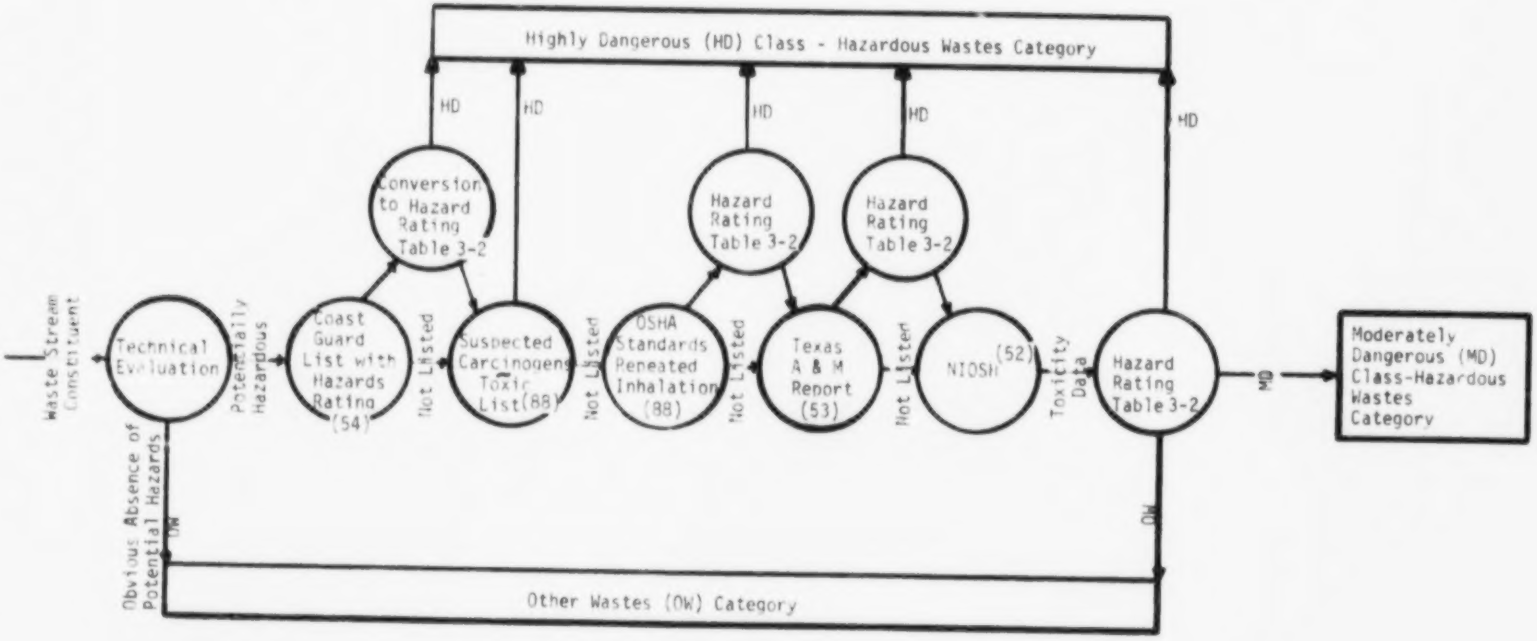
Waste Stream Constituent
Technical Evaluation
Potentially Hazardous
Obvious Absence of Potential Hazards
OW
Coast Guard List with Hazards Rating (54)
Conversion to Hazard Rating Table 3-2
HD
Not Listed
Suspected Carcinogens Toxic List (88)
HD
Not Listed
OSHA Standards Repeated Inhalation (88)
Hazard Rating Table 3-2
HD
Not Listed
Texas A & M Report (53)
Hazard Rating Table 3-2
HD
Not Listed
NIOSH (52)
Toxicity Data
Hazard Rating Table 3-2
HD
MD
OW
Highly Dangerous (HD) Class - Hazardous Wastes Category
Moderately Dangerous (MD) Class-Hazardous Wastes Category
Other Wastes (OW) Category

Figure A-2. Hazard Evaluation System

Under the considerations noted above, hazardous wastes was the designation for all waste streams which contained one or more components which were:

- Classified as moderately dangerous or highly dangerous by the standards of Table 3-1.
- Any of the following specific substances or types of substances: asbestos, arsenic, beryllium, cadmium, chromium,[1] copper, cyanides,[2] lead, mercury, halogenated hydrocarbons, pesticides, selenium and zinc.
- Assessed as explosive (as defined below), carcinogenic, oncogenic (tumor forming), teratogenic, mutagenic, subject to bioaccumulation to toxic level[3], strongly corrosive or a strong sensitizer.

In addition, where the physical characteristics of the waste stream iteself were such as to endanger, actually or potentially, life or limb, the stream was classified as a hazardous waste, e.g., waste streams discharged directly to the environment at high temperature or high pressure could be classified as hazardous wastes.

The term "other wastes" was applied to all waste streams not classified as hazardous wastes.

The definitions given below for previously used terms are cited in part from the California Hazardous Waste Law and the California Hazardous Substances Labeling Act:

Strongly Corrosive:	Any substance which by contact with living animal tissue will cause destruction of the tissue by chemical action.
Explosive:	Any substance which generates a sudden, rapid rise in pressure through decomposition, heat, or other means, and may be initiated by self-reaction, mechanical, electrical or thermal shock.
Strong Sensitizer:	A substance which will cause in normal living tissue through an allergic or photodynamic process, a hypersensitivity which becomes evident on reapplication of the same substance.

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[1] Hexavalent chromium compounds only

[2] Except ferrocyanide compounds

[3] All bioconcentratable materials were raised to the next higher Hazard Classification.

Waste components were classified in accordance with the standards of Table 3-1, and the procedure and sequence shown in Figure A-2. The substances and ionic species listed above (asbestos, arsenic, beryllium, etc.), were classified as highly dangerous components.

The detailed process descriptions cited earlier in this section were performed for each of the 373 organic chemicals and technical pesticides. This study derived for each product the identity of the waste components discharged in process waste streams, their destination, and the waste generation factors for the individual components. Information on the chemical processes used for production was obtained from the references cited, but actual quantities of the chemical components in the waste streams were available for only 50 percent of the commodity chemicals in this study.

For those process waste streams on which no literature or production source data were available, this study used information on the chemistry and unit operations of the production process, and on related chemicals, related chemical reactions, and related processes as the bases for estimation. Analogous reactions (e.g., esterification) were assumed to yield analogous waste stream components and waste generation factors and to require the use of like process equipment. The quantities of dissolved solids in the waste streams per pound of product were calculated from simple molar relationships. Where products were water-soluble, and distillation, flashing and the like were used as the final purification step, it was assumed that purification was complete. Where products were only slightly water soluble, a small amount over and above the quantity in solution was assumed to be mechanically entrained in the process waste stream.

To summarize: A listing of process waste components were developed for each of the air, water and land process waste streams of each organic chemical and technical pesticide. A waste generation factor (metric tons per metric ton of product) was derived for each waste component. Each waste component was subjected to a hazard analysis, in accordance with the "Hazard Evaluation System" of Figure A-2, and rated as other wastes, moderately dangerous or highly dangerous. The 1977 (and 1983)* land disposal probability, based on the Federal Water Pollution Control Act Amendments (P.L.92-500), and pertinent air pollution regulations, was assessed for each hazardous-rated component now disposed of to water or to air. Production increase factors (based on projected growth in Gross National Product)** of 1.10 and 1.216 were applied to the 1973 factors to obtain the 1977 and 1983 factors. For each organic chemical or group, colligative waste generation factor sets for land disposal in the three categories (other wastes, moderately dangerous and highly dangerous) were compiled for 1973, 1977 and 1983.

The colligative waste generation factors in the three hazard classes noted for each chemical were multipled by the rates of production of the chemical in each state as described in Figure A-3, and the products summed by SIC listing for the chemicals for each of the time frames (1973, 1977 and 1983). The results of these calculations were the statistical summaries presented on process waste streams destined for land disposal.

The procedure used for the pesticides preparations and formulations industry was much simpler because less data were available. Based on production-source supplied information, pesticide preparation and formulation wastes destined for land disposal were estimated as 1 metric ton for each 300 metric tons of product. Based on the ratio of total technical organic pesticides produced nationally in 1973 to the estimate of total pesticide preparations produced nationally, approximately 40 percent of this land-destined waste was estimated to be active pesticide ingredients, and therefore, hazardous components of this total. Based on an analysis of this fraction (the hazardous components) in the active ingredients, 60 percent was classified as highly dangerous. The statistical summaries shown for SIC 2879 are the results of the use of these factors and the production increase factors for 1977 and 1983 against the state production totals for pesticide preparations and formulations.

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* The land disposal probability for 1977 was presumed to be the same as for 1983, since, for simplification of calculations it had been assumed that the industries would meet the 1983 requirements of the Water Pollution Control Act as amended.

** There has been a close correlation between GNP and organic chemicals production for the past 10 years.

Product Name	Product Number	SIC Number	Process Number	Waste Components and Destination	Waste Components Generation Factor	Hazard Rating	1973 Total Wastes* to Land	1973 Total Hazardous Components to Land	1973 Total Highly Dangerous Components to Land	1977 Total Wastes* to Land	1977 Total Hazardous Components to Land	1977 Total Highly Dangerous Components to Land	1977 Production Increase Factor	1983 Production Increase Factor
							F_1	F_2	F_3	F_4	F_5	F_6	P_1	P_2

1973 Metric tons total waste* to land disposal generated per year = C x Production (million pounds per year) x F_1
Metric tons total hazardous components to land per year = C x Production (million pounds per year) x F_2
Metric tons total highly dangerous components to land per year = C x Production (million pounds per year) x F_3

1977 Metric tons total waste* to land disposal generated per year = C x Production (million pounds per year) x F_4 x P_1
Metric tons total hazardous components to land per year = C x Production (million pounds per year) x F_5 x P_1
Metric tons total highly dangerous components to land per year = C x Production (million pounds per year) x F_6 x P_1

1983 Metric tons total waste* to land disposal generated per year = C x Production (million pounds per year) x F_4 x P_2
Metric tons total hazardous components to land per year = C x Production (million pounds per year) x F_5 x P_2
Metric tons total highly dangerous components to land per year = C x Production (million pounds per year) x F_6 x P_2

C x (Production, million pounds per year) = Production, metric tons per year

C = 453.59244 metric tons per million pounds.

*Water-free basis

Figure A-3. Calculations — Total Annual Quantities Generated and Sent to Land Disposal Waste Streams*, Hazardous Components, and Highly Dangerous Components

The calculation of process wastes going to land disposal for the technical organic pesticides product group (SIC 28694) was similar to that used for the remainder of the organic chemicals. For each of the 17 groups of analogous pesticides, representative members were chosen for process analyses and waste generation factor determination. Each member of the group was assumed to have the same product component and non-product component waste generation factors as the average of the group's representative members. The colligative waste generation factors for each technical pesticide were calculated on this basis, and the remaining calculations were identical with those performed on the rest of the organic chemicals.

The components and quantities of hazardous wastes generated by each plant in the GOCO portion of the explosives industry were available from reports furnished by the U.S. Army Armament Command(18), or from prior studies by TRW(59, 73, 87). The hazard evaluation system cited earlier was employed for rating the waste components, and the quantities were summarized for each state with an active Army ammunition plant or other defense sector explosives industry plant.

For the private sector of the explosives industry, the waste generation factors obtained from the Institute of Makers of Explosives for a prior EPA study(89) were employed to calculate the quantities of waste explosive for each state from the production statistics. The only hazardous wastes reported in this study for the nondefense explosives industry are the waste explosives, since the data obtained from the literature and from the private plant visits were deemed insufficiently representative of the more than 600 plants in the United States.

TREATMENT AND DISPOSAL TECHNOLOGY EVALUATION

The treatment and disposal technology used for hazardous wastes destined for land disposal was identified and described on the basis of the following standards:

Level I	The typical broad average practice(s) for the industry or product group.
Level II	The best technology available in current commercial practice.

Level III Technology currently known and assessed as providing adequate health and environmental protection. The interpretation of currently known technology included technology now available only at the bench or pilot plant level.

COST ANALYSES

Cost estimates for the treatment processes applied to the typical and actual plants chosen as representative of the industry or product group were developed. The standard cost engineering techniques utilized included:

- Cost of capital was assumed to be 10 percent.
- Straight-line depreciation based upon estimated life and capital outlay less salvage value was used on capital items.
- Operating and maintenance costs used were the normal costs for these functions, excluding power and energy costs, which were stated separately.
- Land costs took into account reduced market value where required due to disposal operations.

APPENDIX B

TEXAS AND CALIFORNIA STATE ACTS AND REGULATIONS ON TREATMENT AND DISPOSAL

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INJECTION WELL ACT
STATE OF TEXAS

Article 7621b, V.T.C.S.
as amended by 61st Legislature,
Regular Session, 1969

Section 1. SHORT TITLE. This Act may be cited as the Injection Well Act.

Section 2. DEFINITIONS. As used in this Act, unless the context requires a different definition:

(a) "board" means the Texas Water Quality Board;

(b) "commission" means the Texas Railroad Commission;

(c) "Person" means individual, corporation, organization, government or governmental subdivision or agency, business trust, partnership, associatiation, or any other legal entity;

(d) "Pollution" means the alteration of the physical, chemical, or biological quality of, or the contamination of, water that renders the water harmful, detrimental, or injurious to humans, animal life, vegetation or property, or to public health, safety, or welfare, or impairs the usefulness or the public enjoyment of the water for any lawful or reasonable purpose;

(e) "Industrial and municipal waste" is any liquid, gaseous, solid or other waste substance or a combination thereof resulting from any process of industry, manufacturing, trade, or business or from the development or recovery of any natural resources, or resulting from the disposal of sewage, or other wastes of cities, towns, villages, communities, water districts and other municipal corporations, which may cause or might reasonably be expected to cause pollution of fresh water;

(f) "fresh waters" means waters whose bacteriological, physical and chemical properties are such that they are suitable and feasible for beneficial use for the purposes permitted by law;

(g) "casing" means any material utilized to seal off strata at and below the earth's surface;

(h) "injection well" means an artificial excavation or opening into the ground, made by means of digging, boring, drilling, jetting, driving or otherwise, and made for the purpose of injecting, transmitting, or disposing of industrial and municipal waste into a subsurface stratum; also a well initially drilled for the purpose of producing oil and gas when used for the purpose of transmitting, injecting, or disposing of industrial and municipal waste into a subsurface stratum; but "injection well" does not include any surface pit, excavation or natural depression used to dispose of industrial and municipal waste.

(i) Notwithstanding any provisions of Subsection (e) of this section, "waste arising out of or incidental to the drilling for or the producing of oil or gas" includes, but is not limited to, the following items when they result from such drilling or producing activities; salt water, brine, sludge, drilling mud, and other liquid or semi-liquid waste materials.

Section 3. INDUSTRIAL AND MUNICIPAL WASTES; APPLICATIONS TO BOARD.

(a) Before any person commences the drilling of an injection well, or before any person converts any existing well into an injection well, for the purpose of disposing of industrial and municipal waste, other than waste arising out of or incidental to the drilling for or the producing of oil or gas, a permit therefore shall be obtained from the board. The board shall be available upon request without cost. The board shall require the furnishing of such information by an applicant as the board may deem necessary to discharge properly the duties imposed by this Act. An application for a permit to drill an injection well, or to convert any existing well to an injection well, shall be accompanied by a fee of $25.00 which shall be collected by the board for the benefit of the state.

(b) Upon receipt by the board of an application in proper form and accompanied by the necessary fee for a permit to drill an injection well, or to convert an existing well to an injection well, the board shall cause an inspection to be made of the location of the proposed injection well to determine local conditions and the probable effect of the injection well, and shall cause an evaluation to be made to determine the requirements for the setting of casing, as provided in Section 5 of this Act.

(c) The board shall also send copies of every application received in proper form to the Texas Water Development Board, the Texas State Department of Health, the Texas Water Well Drillers Board, and to such other persons as the board may designate. The agencies and other persons to whom a copy of the application is sent may make recommendations to the board concerning any aspect of the application, and shall have such reasonable time to do so as the board may prescribe.

(d) The board may hold a public hearing upon an application if it is deemed necessary and in the public interest, but otherwise, a public hearing is not required. Notice of any public hearing and its procedure shall be under such terms and conditions as the board may prescribe.

(e) Any person applying to the board for a permit to inject industrial and municipal waste, other than waste arising out of or incidental to the drilling for or the producing of oil or gas, into a subsurface stratum shall submit with the application a letter from the commission stating that the drilling of the injection well and the injection of industrial and municipal waste into the subsurface stratum will not endanger or injure any oil or gas formation.

Section 4. ISSUANCE OF PERMIT; CASING OF WELL; RULES AND REGULATIONS.

If the board or commission, as the case may be, finds that the installation of the injection well is in the public interest, will not impair any existing rights, and that by requiring proper safeguards both ground and surface fresh waters can be protected adequately from pollution, the board or commission, as appropriate, may grant the application in whole or in part and issue a permit with such terms, provisions, conditions and requirements as are reasonably necessary to protect fresh waters from pollution by industrial and municipal waste. Specifically, the board or commission shall require that the injection well shall be so cased as to protect all fresh waters from pollution by the intrusion of industrial and municipal waste. The casing shall be set at such depth, with such materials, and in such manner as the board or the commission may require. The board or the commission, in establishing the depth to which casing shall be installed, shall consider known geological and hydrological conditions and relationships, the foreseeable future economic development in the area, and the foreseeable future demand for the use of the fresh waters in the locality. The board or commission may also require the permittee to keep and furnish a complete and accurage record of the depth, thickness and character of the different strata penetrated in the drilling of the well. In the event an existing well is to be converted to an injection well, the board or commission may require that the applicant furnish an electric log or a drilling log of the existing well. A copy of every permit issued by the board shall be furnished by the board to the commission, the Texas Water Development Board, the Texas State Department of Health, and the Texas Water Well Drillers Board. A copy of every permit issued by the commission shall be furnished by the commission to the board, which shall in turn forward copies to the other agencies named in the preceding sentence. The board and the commission each shall adopt rules, regulations and procedures reasonably required for the performance of the duties, powers and functions prescribed for each by this Act. Copies of any rules or regulations under this Act proposed by the board or the commission shall, before their adoption, be sent by each of these agencies to the other agency, and also to the

Texas Water Development Board, the State Department of Health, the Texas Water Well Drillers Board, and such other persons as the originating agency may designate. Any agency or person to whom the copies of proposed rules and regulations are sent may submit comments and recommendations to the agency proposing the rules and regulations, and shall have such reasonable time to do so as the originating agency may prescribe.

Section 5. WILLING COPY OF PERMIT. Any person receiving a permit to inject industrial and municipal waste, shall, before injection operations are begun, file a copy of the permit with the health authorities of the county, city and town where the well is located.

Section 6. ENFORCEMENT. Any person who fails to comply with the provisions of this Act, or with any rule or regulations promulgated by the board or the commission under this Act, or with any term, condition or provision in his permit issued pursuant to this Act, shall be subject to a civil penalty in any sum not exceeding One Thousand Dollars ($1,000.00) for each day of non-compliance and for each act of non-compliance, as the court may deem proper. The action may be brought by the board or the commission, as appropriate, in any court of competent jurisdiction in the county where the offending activity is occurring or where the defendant resides. Full authority is also given the board or commission, as appropriate, to enforce by jurisdiction in the county where the offending activity is occurring, any and all reasonable rules and regulations promulgated by it which do not conflict with any law, and all of the terms, conditions and provisions of permits issued by the board or commission pursuant to the provisions of this Act. At the request of the board or the commission, the attorney general shall institute and conduct a suit in the name of the State of Texas for injunctive relief or to recover the civil penalty, or for both the injunctive relief and civil penalty, authorized in this section. Any party to a suit may appeal from a final judgment as in other civil cases. The obtaining of a permit under the provisions of this Act by a person shall not act to relieve that person from liability under any statutory law or the Common Law.

REGULATIONS
STATE OF CALIFORNIA

Subchapter 15
Waste Disposal to Land

Article I
General Provisions

Section 2500 DEFINITION OF TERMS. (a) "Disposal site" means any place used for the disposal of solid or liquid wastes. It does not include sewage treatment ponds or locations of waste disposal from pipes or ditches into waters of the state.

(b) "Disposal Area" is the actual area of the site which has received or is receiving wastes.

(c) "Percolate" is fluid resulting from the percolation or draining of a liquid through a waste substance.

(d) "Usable" ground or surface water includes potentially usable water.

(e) "Hydraulic continuity" is a condition existing when fluid occupying an interstice of a saturated material is able to move, under a head differential imposed by gravity, to adjoining interstices and/or surface channels containing fluid.

(f) "Capillary fringe" is the partly saturated zone immediately above the water table in which water is held by capillary forces.

Section 2501. DISPOSAL AT CLASSIFIED SITES. Disposal of either solid or liquid wastes at disposal sites shall be only at those sites which have been classified by the appropriate regional water quality control board in the establishment of waste discharge requirements in conformity with this subchapter unless requirements are waived by the regional board pursuant to Section 2530 (c).

Article 2
Classification of Waste Disposal Sites

Section 2510. CLASS I DISPOSAL SITES. Class I disposal sites are those at which protection is provided for the quality of ground and surface waters from all wastes as determined by the following criteria:

(a) The disposal area is underlain by non-waterbearing geological formations or by unusable groundwater which is isolated from other usable waters.

(b) Geological conditions must be naturally capable of preventing both vertical and lateral continuity between liquids and gases from waste in the site and usable groundwaters, or have been modified to achieve such capability in a manner acceptable to the regional board.

(c) Underlying geological formations which contain rock fractures or fissures of questionable permeability must be sealed to provide a competent barrier to the movement of liquids or gases from the disposal site.

(d) Surface drainage from tributary areas outside the site must be precluded from entering areas of the site which have received or are receiving wastes until the site is closed in accordance with requirements of the regional board.

(e) Subsurface flow into the disposal area and percolate resulting from internal drainage shall be contained within the site unless other disposition is made in accordance with requirements of the regional board.

(f) Class I sites made suitable for use by man-made physical barriers shall not be located where improper operation or maintenance of man-made physical containment structures will impair usable ground or surface water quality or create a hazard to public health.

(g) Class I sites shall not be located over zones of active faulting or where other forms of geological change would reduce the capability of natural or man-made features to prevent continuity with usable groundwaters.

(h) Class I sites for unlimited use must not be subject to washout or inundation by floods.

(i) Sites which comply with a,b,c,e,f, and g but would be subject to inundation by a flood of greater than 100 year frequency may be classified by the regional board as a limited Class I Disposal Site subject to waste discharge requirements which would include limits on (1) the type and quantity of material entering the site, (2) the concentration of material in the waste deposited on the site, (3) the amount of residue present or remaining on the site after evaporation of the liquid.

Section 2511 CLASS II DISPOSAL SITES. Class II disposal sites are those at which protection is provided to water quality from Group 2 and Group 3 wastes as determined by the following criteria:

(a) If the site has hydraulic continuity with usable ground or surface water, there must be physical features to prevent degradation of groundwater quality due to liquid or gases emanating from the waste. The types of physical features and the extent of protection of groundwater quality further divides Class II sites into two general categories.

(1) A Class II-1 site is isolated from vertical hydraulic continuity with usable groundwater by natural impervious geological formations or artificial barriers, or it is underlain by non-waterbearing rocks, but it may have lateral hydraulic continuity with groundwater basins containing usable groundwater.

(2) A Class II-2 site may have vertical hydraulic continuity with usable groundwater but it is either modified by artificial barriers or has natural geological and hydraulic features, such as soil type and depth to groundwater, which prevent degradation of the quality of usable groundwater underneath the site.

(b) Class II disposal sites located in flood plains shall be protected by natural or artificial features so as to assure protection from washout and flooding which could occur as a result of floods having a predicted frequency of once in 100 years.

(c) Surface drainage from tributary areas shall be precluded from contacting waste in the site.

(d) Gases emanating from waste in the site will be prevented from degrading groundwater during the predictable life of the site by physical features or rate of groundwater movement in hydraulic continuity with the site.

(e) Internal drainage of the site or subsurface flow into the site and the depth at which water soluble materials are placed shall be controlled during construction and operation of the site to minimize percolate and assure that the waste material will be above the highest anticipated elevation of the capillary fringe of the groundwater. Such control may include discharge from the site subject to waste discharge requirements prescribed by the regional board.

Section 2512 CLASS III DISPOSAL SITES. Class III disposal sites are those at which protection is provided for water quality from Group 3 wastes as determined by the following criteria:

(a) Each site is located and constructed to prevent erosion or transport of deposited material.

(b) Operation or construction of the site shall not result in degradation of surface water quality due to erosion of adjacent land areas.

Section 2513 WASTE WELLS. Wells suitable for the disposal of wastes shall provide protection to usable groundwater from wastes of Groups 1 or 2 in any form as determined by the following conditions:

(a) The receiving formation shall not be in hydraulic continuity with any usable groundwater.

(b) The construction and injection procedure will be such that no paths of percolation are developed which will permit the movement of the waste to a usable aquifer or to the surface.

(c) Certification has been provided by the California Division of Oil and Gas that construction and operation of waste wells under its jurisdiction will conform to regulations of the Division.

(d) Wells used for the disposal of wastewater and the resultant recharge of groundwater, or for the disposal of used irrigation water, under requirements adopted by the regional board may be exempted from provisions a, b, and c.

(e) Construction and operation of sewer wells shall be in conformance with applicable regulations for the protection of public health.

Article 3
Classification of Wastes Discharged to Land

Section 2520 GROUP I WASTES. Group I wastes consist of or contain substances directly harmful or dangerous to the health and safety of man or other living organisms during disposal operations or in the event of mixing with usable water, or substances which may significantly impair the quality of usable waters. Examples include but are not limited to the following:

(a) Municipal Wastes
  (1) Saline fluids from water or waste treatment and reclamation processes.
  (2) Community incinerator ashes.
(b) Industrial Wastes
  (1) Saline brine from food processing, oil well production, water treatment, industrial processes and geothermal plants.
  (2) Toxic or hazardous fluids from industrial processes or resulting from spills, or blowdown. These fluids may include spent cleaning fluids, petroleum fractions, chemicals, acids, alkalies, phenols, and spent washing fluids.

(3) Substances from which toxic materials can leach such as process ashes, chemical mixtures, and mine tailings.

(c) Agricultural Wastes

(1) Agricultural chemicals such as herbicides, insecticides, fungicides, and chemical fertilizer and their containers to the extent they are actually toxic or hazardous to human health or water quality after mixing with water.

(d) Other toxic wastes such as compounds of arsenic or mercury, chemical warfare agents, etc.

Section 2521 GROUP 2 WASTES. Group 2 wastes consist of or contain decomposable organic material which does not include substances which are toxic or significantly impair the quality of usable water. Group 2 wastes may be deposited in either a Class II-1 or II-2 site unless specifically limited by the regional board or the regulations of other appropriate authorities. Examples include but are not limited to the following:

(a) Municipal and industrial wastes

(1) Garbage consisting of putrescible wastes from processing, preparation, cooking, and serving of food

(2) Market wastes from handling, storage, and processing of produce

(3) Construction and demolition materials containing paper, cardboard, tin cans, wood, glass, bedding, rubber products, roofing paper, wallpaper, stumps, and other materials

(4) Rubbish and street refuse consisting of putrescible and non-putrescible material such as sweepings, dirt, leaves catch basin dirt, litter, yard clippings, glass, paper, wood and metals in various forms or combinations.

(5) Dead animals

(6) Abandoned vehicles

(7) Sewage treatment residue including solids from screens and grit chambers and sludge

(8) Water treatment residue including solid organic matter collected on screens and in settling tanks

(9) Ashes from household burning

(10) Infectious materials and hospital or laboratory wastes authorized for disposal to land by official agencies charged with control of plant, animal, or human disease.

(11) Magnesium and other highly flammable or pyrophoric materials

(12) Miscellaneous industrial wastes such as metals and metal products, wood and paper materials, oils, chemicals and sludges which are not toxic or hazardous within the definition of Group I wastes.

(b) Agricultural wastes

(1) Stalks, vines, green drops, culls, stubble, hulls, lint and seed from field and seed crops

(2) Vines, stalks, roots, green drops, and culls from vegetable crops

(3) Stumps, prunings and trimmings, culls, and green drops from fruit and nut crops

(4) Manures

(5) Dead animals or materials of animal origin.

Section 2523 DISPOSAL OF GROUP I WASTES IN CLASS II - I SITES.

Regional board may allow the disposal of certain Group I wastes in a Class II-1 site when, in the judgment of the board, such disposal will not constitute a threat to water quality. Such selected disposal of specific Group I wastes shall be subject to terms and conditions considered appropriate by the regional board.

APPENDIX 1 (From State of California Statutes of 1972, Vol. 1, p. 2387-2393).

Assembly Bill No. 598

CHAPTER 1236

An act to add Chapter 6.5 (commencing with Section 25100) to Division 20 of the Health and Safety Code, relating to waste materials

[Approved by Governor December 13, 1972. Filed with
Secretary of State December 13, 1972.]

LEGISLATIVE COUNSEL'S DIGEST

AB 598, Dunlap. Industrial waste.

Requires the State Department of Public Health to adopt regulations for the handling, processing, and disposal of hazardous and extremely hazardous wastes, as defined, to protect against hazards to the public health, to domestic livestock, and to wildlife. Specifies procedure for such adoption. Makes it unlawful to dispose of any such waste except as provided for in such regulations.

Requires the department to prepare a listing of wastes determined to be hazardous and extremely hazardous.

Requires any producer of a material which he may reasonably consider to be an extremely hazardous waste and which he does not intend to recycle for reuse to notify the department of his intent to dispose of such waste.

Requires after January 1, 1974, the person producing a hazardous waste listed by the department to provide operators of transportation equipment with a list setting forth specified information. Requires such list to be released to person responsible for disposal and to be shown to department officials, officers of the California Highway Patrol upon demand, or any local public officer as designated by the director.

Requires the department to adopt and enforce rules and regulations re such lists. Specifies documents required by other state or federal agencies meeting specified conditions shall meet such requirement.

Creates a hazardous waste technical advisory committee and specifies membership and duties of such committee.

Provides civil enforcement procedures for provisions of act. Authorizes state health officials to enter at a reasonable hour of the day specified facilities in order to carry out the purposes of the act.

Requires the director to establish as specified, and operators of disposal sites where wastes subject to such provisions are disposed to pay to the director, fees sufficient for, but not in excess of, amounts necessary for administration of provisions re such wastes.

Specifies related powers and duties of the department.

Operative July 1, 1973.

The people of the State of California do enact as follows:

SECTION 1. Chapter 6.5 (commencing with Section 25100) is added to Division 20 of the Health and Safety Code, to read:

CHAPTER 6.5. HAZARDOUS WASTE CONTROL

Article 1. Findings and Declarations

25100. The Legislature finds that increasing quantities of hazardous wastes are being generated in the state and that without adequate safeguards for handling and disposal, such wastes can create conditions which threaten the public health and safety and create hazards to wildlife.

25101. The Legislature therefore declares that in order to prevent such hazardous conditions it is in the public interest to establish regulations and to maintain a program to provide for the safe handling and disposal of hazardous wastes.

Article 2. Definitions

25110. Unless the context indicates otherwise the definitions in this article govern the construction of this chapter.

25111. "Department" means the State Department of Public Health.

25112. "Director" means the Director of Public Health.

25113. "Disposal" means to abandon, deposit, inter or otherwise discard waste as a final action after their use has been achieved or a use is no longer intended.

25114. "Disposal site" means the location where any final deposition of solid waste occurs.

25115. "Extremely hazardous waste" means any hazardous waste or mixture of hazardous wastes which, if human exposure should occur, may likely result in death, disabling personal injury or illness during, or as a proximate result of, any disposal of such waste or mixture of wastes because of its quantity, concentration, or chemical characteristics.

25116. "Handling" means the transport, transfer from one place to another, or packaging of hazardous and extremely hazardous waste.

25117. "Hazardous waste" means any waste material or mixture of wastes which is toxic, corrosive, flammable, an irritant, a strong sensitizer, which generates pressure through decomposition, heat or other means, if such a waste or mixture of wastes may cause substantial personal injury, serious illness or harm to wildlife, during, or as a proximate result of any disposal of such wastes or mixture of wastes. The terms "toxic," "corrosive," "flammable," "irritant," and "strong sensitizer" shall be given the same meaning as in the California Hazardous Substances Act (Chapter 13 (commencing with Section 28740) of Division 21).

25118. "Person" also includes any city, county, district, the state or any department or agency thereof.

25119. "Processing" means to treat, detoxify, neutralize, incinerate, biodegrade, or otherwise process a hazardous waste to remove its harmful properties or characteristics for disposal in accordance with regulations established by the department in conjunction with any other agency authorized to regulate or control hazardous waste.

25120. "Processing facility" means any facility or location where any final treatment, incineration, processing or deposition of hazardous waste occurs.

25121. "Recycle" means to process, alter, or otherwise treat a hazardous waste for subsequent use.

25122. "Waste" means any material for which no use or reuse is intended and which is to be discarded.

Article 3. Hazardous Waste Technical Advisory Committee

25130. The department shall establish a hazardous waste technical advisory committee to provide consultation to the department concerning matters covered by the chapter. The committee shall advise the department on the development of standards, rules, and regulations for hazardous waste management, and shall supply recommendations concerning methods by which existing hazardous waste management practices and the laws regulating them may be supplemented and improved and their administration financed.

25131. The committee shall consist of seven members appointed by the director who shall be knowledgeable in hazardous waste management. The members shall insofar as possible represent the interests of the public, local and regional government, agriculture, manufacturing industry, local health departments, and the waste management industry.

25132. At least two members of the committee shall represent the interests of the public and shall have no financial interest in any of the recommendations or studies of the committee. Such financial interest shall include, but not be limited to, service as a consultant to any person specializing in waste disposal, as a tenant or landlord of property used for waste disposal, or as an attorney of a party with a direct financial interest in hazardous waste disposal.

25133. Members of the hazardous waste technical advisory committee shall serve without compensation, but shall be entitled to per diem and reimbursement for travel expenses incurred as a result of official committee business.

Article 4. Listings

25140. The department shall prepare, adopt and may revise when appropriate, a listing of the wastes which are determined to be hazardous, and a listing of the wastes which are determined to be extremely hazardous. When identifying such wastes the department shall consider, but not be limited to, the immediate or persistent toxic effects to man and wildlife and the resistance to natural degradation or detoxification of the wastes.

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Article 5. Standards

25150. The department shall adopt, and may revise when appropriate, minimum standards and regulations for the handling, processing, and disposal of hazardous and extremely hazardous wastes to protect against hazards to the public health, to domestic livestock, and to wildlife. Before adoption of such standards and regulations the department shall consult with all agencies of interested local governments and secure technical assistance from the Department of Agriculture, the Department of the California Highway Patrol, the Department of Fish and Game, the Department of Industrial Relations, Division of Industrial Safety, the State Air Resources Board, the State Water Resources Control Board and the State Fire Marshal.

25151. The department may adopt varying standards for different areas of the state depending on population density, climate, geology and other factors relevant to hazardous waste processing and disposal.

25152. Before adopting or revising minimum standards and regulations for the handling, processing, and disposal of hazardous and extremely hazardous wastes, the department shall hold at least one public hearing in Sacramento, or in a city within the area of the state to be affected by the proposed regulations. The department shall adopt the proposed regulations after making changes or additions that are appropriate in view of the evidence and testimony presented at the public hearing or hearings.

25153. Any person who is producing a waste material which he may reasonably consider to be an extremely hazardous waste, and which he does not intend to recycle for reuse and intends to dispose of as waste, shall notify the department of his intent to dispose of such waste material.

25154. After the effective date of the regulations adopted by the department pursuant to this article, it shall be unlawful for any person to dispose of any hazardous or extremely hazardous waste except as provided for in such regulations.

25155. After January 1, 1974, no extremely hazardous waste as listed by the department pursuant to Section 25140, may be disposed of without prior processing to remove its harmful properties or as specified by the regulations of the department for the handling and disposal of the particular extremely hazardous waste.

Article 6. Transportation

25160. After January 1, 1974, the person producing a hazardous waste listed by the department pursuant to Section 25140 shall provide the driver of any truck, a crew member of any train, or the captain of any vessel carrying such hazardous wastes with a list setting forth the hazardous wastes carried, the amount of such waste, the general chemical and mineral composition of such waste listed by probable maximum and minimum percentages, and the origin and destination of any such waste carried. Such list, when appropriate, may include information on antidotes, first aid, or safety measures to be taken in case of accidental contact with the particular hazardous waste being carried. The person carrying, or handling the hazardous waste shall have the list in his possession while carrying or handling the hazardous waste and shall release the list to a person responsible for disposal of the hazardous waste at the time of delivery. Such list shall be shown upon demand to any department official, officer of the California Highway Patrol, or any local public officer as designated by the director.

25161. The department shall adopt and enforce all rules and regulations, including the form and content of the list, necessary and appropriate to accomplish the purposes of Section 25160.

25162. Documents required by other agencies of the state or the federal government which describe the character and amount of hazardous wastes being carried shall satisfy the requirement of Section 25160.

Article 7. Other Provisions

25170. The department in performing its duties under this chapter shall:

(a) Establish procedures for evaluation and coordination of research and development regarding methods of hazardous waste handling and disposal and may conduct appropriate studies relating to hazardous wastes.

(b) Maintain a technical reference center on hazardous waste disposal, recycling practices, and related information for public and private use.

(c) Render technical assistance to state and local agencies in the planning and operation of hazardous waste programs.

(d) Provide for appropriate surveillance of hazardous waste processing and disposal practices in the state.

25171. No provision of this chapter shall be construed to require disposal of hazardous waste at the site of production, provided, that the transportation of such waste conforms to all applicable regulations.

25172. No provision of this chapter shall limit the authority of any state or local agency in the enforcement or administration of any provision of law which it is specifically permitted or required to enforce and administer.

25173. The department shall establish procedures to insure that trade secrets used by a person regarding methods of hazardous waste handling and disposal are utilized by the director, the department, or any authorized representative of the department only in connection with the responsibilities of the department pursuant to this chapter, and that such trade secrets are not otherwise disseminated by the director, the department, or any authorized representative of the department without the consent of the person. "Trade secrets," as used in this section, may include, but are not limited to, any formula, plan, pattern, process, tool, mechanism, compound, procedure, production data, or compilation of information which is not patented, which is known only to certain individuals within a commercial concern who are using it to fabricate, produce, or compound an article of trade or a service having commercial value and which gives its user an opportunity to obtain a business advantage over competitors who do not know or use it.

25174. Beginning January 1, 1974, each operator of any site at which hazardous wastes are disposed shall pay a fee to the director for each list or other document which such operator receives pursuant to Article 6 (commencing with Section 25160). The director shall establish a schedule of the fees to be paid to the director by such operator for each disposal of hazardous waste listed on such a list or document, which shall provide revenues which shall not exceed the amount necessary, but shall be sufficient, to cover all costs incurred in the administration of this chapter. Such fees shall be deposited each month in the Hazardous Waste Control Account in the General Fund.

Article 8. Enforcement

25180. The minimum standards and regulations adopted by the department pursuant to Section 25150 shall be enforced by the department or any local health officer or any local public officer as designated by the director.

25181. Whenever, in the judgment of the department, any person has engaged in or is about to engage in any acts or practices which constitute or will constitute a violation of any provision of this chapter or any rule, regulation, or order issued thereunder, and at the request of the department, the district attorney of the county in which such acts or practices occur or will occur or the Attorney General may make application to the superior court for an order enjoining such acts or practices, or for an order directing compliance, and upon a showing by the department that such person has engaged in or is about to engage in any such acts or practices, a permanent or temporary injunction, restraining order, or other order may be granted.

25182. Every civil action brought under the provisions of this chapter at the request of the department shall be brought by the district attorney or Attorney General in the name of the people of the State of California and any such actions relating to the same processing or disposal of hazardous wastes may be joined or consolidated.

25183. Any civil action brought pursuant to this chapter shall be brought in the county in which the processing or disposal of hazardous waste is made or proposed to be made.

25184. In any civil action brought pursuant to this chapter in which a temporary restraining order, preliminary injunction, or permanent injunction is sought, it shall not be necessary to allege or prove at any stage of the proceeding that irreparable damage will occur should the temporary restraining order, preliminary injunction, or permanent injunction not be issued; or that the remedy at law is inadequate, and the temporary restraining order, preliminary injunction, or permanent injunction shall issue without such allegations and without such proof.

25185. The director or any duly authorized representative of the department may at any reasonable hour of the day, enter a factory, plant, construction site, waste disposal site, establishment or any environment where hazardous wastes are stored, handled, processed or disposed of, in order to carry out the purposes of this chapter.

SEC. 2. This act shall become operative on July 1, 1973.

HAZARDOUS WASTE REGULATIONS, STATE OF CALIFORNIA

Title 22

Division 4. Environmental Health

Chapter 1. Introduction

Article 1. Definitions

60001. Department. Whenever the term "department" is used in this division, it means the State Department of Health, unless otherwise specified.

60003. Director. Whenever the term "director" is used in this division, it means the Director, State Department of Health, unless otherwise specified.

Chapter 2. Hazardous Waste

Article 1. General

60100. Definitions. The definitions set forth in Article 2. (commencing with Section 25110) of Chapter 6.5 of Division 20 of the Health and Safety Code shall govern the construction of this chapter.

60105. Minimum Standards. Nothing in this chapter shall be construed as relieving any person involved in the management of hazardous waste from the obligations of obtaining all required permits, licenses, or other clearances, and complying with all orders, laws, regulations, or other requirements of duly authorized and constituted regulatory or enforcement agencies, such as, but not limited to, health authorities, state and local water and air pollution control agencies, local land use authorities, fire authorities, etc.

Article 2. Hazardous Wastes

66680. Hazardous Waste List. (a) The following is a listing of materials which, as defined in Section 25122 of the Health and Safety Code as waste, have been determined to be hazardous as defined in Section 25117 of the Health and Safety Code:

(1) Toxic

Acetone cyanhydrin
2-Acetylaminofluorene
Aldrin
Allyl alcohol
Aluminum fluoride
4-Aminodiphenyl
Ammonium arsenate, solid
Ammonium bifluoride
Ammonium fluoride
Ammonium picrate
Aniline oil, liquid
Antimony
Antimony potassium tartrate
Antimony sulfate
Antimony trichloride
Antimony trifluoride
Antimony trioxide
Arsenic acid, liquid or solid
Arsenic bromide, solid
Arsenic chloride, liquid
Arsenic iodide, solid
Arsenic pentaselenide
Arsenic pentoxide, solid
Arsenic, solid
Arsenic sulfide, solid
Arsenic trichloride, liquid
Arsenic trioxide, solid
Arsenical compounds or mixtures
Arsenical dip, liquid
Arsenical dust
Arsenous acid, solid
Arsenous and mercuric iodide solution, liquid
Arsines
Asbestos
Barium carbonate

Barium chloride
Barium cyanide, solid
Barium fluoride
Barium sulfide
Benzene sulfonic acid
Benzene hexachloride
Benzidine
Beryllium compounds
Bidrin
Bomyl
Boranes, Di-, Penta-, Trichloro-
Bordeaux arsenites, liquid or solid
Boron trifluoride
Brucine, solid
Cacodylic acid, solid
Cadmium
Cadmium chloride
Cadmium cyanide
Cadmium fluoride
Cadmium oxide
Cadmium phosphate
Cadmium potassium cyanide
Cadmium sulfate
Calcium arsenate, solid
Calcium arsenite, solid
Calcium fluoride
Carbanolate, Tennik
Carbolic acid, liquid or solid
Carbon tetrachloride
Carbophenothion, Trithion
Chloracetophenone, liquid or solid
Chloral hydrate
Chlordane
Chlorine
Chloracetaldehyde
Chlordinitrobenzol
Chloroform
bis-Chloromethyl ether
Chloro-o-toluidine hydrochloride
Chlorpicrin and methyl chloride mixture
Chlorpicrin
Chromic fluoride
Cocculus, solid
Compound 4072
Copper acetoarsenite, solid

Copper arsenate

Copper arsenite, solid

Copper cyanide

Cyanide of calcium or mixtures, solid

Cyanides of copper, zinc, lead and silver

Cyanides or cyanide mixtures, dry

Cyanide of potassium, liquid or solid

Cyanide of sodium, liquid or solid

Cyanoacetic acid

Cyanogen bromide

Cycloheximide, Acti-Dione

2,4-D

DDT

DDVP

Demeton, Systox

3,3'-Dichlorobenzidine

Dichloroethyl ether

Dichloromethane

1,3-Dichloropropene

Dieldrin

Diglycidyl ether

4-Dimethylaminoazobenzene

Dimethylsulfate

2,4-Dinitroaniline

Dinitrobenzol, solid or liquid

Dinitrochlorbenzol, solid

Dinitrocresol, Sinox, Egetol 30

Dinitrophenol solutions

Dinitrotoluene

Dioxathion, Delnav

Diphenylamine

Diphenylaminechlorarsine, liquid or solid

Diphenylchlorarsine, solid

Disulfoton, Disyston

Dowicide 7, PCP Penchloro

Endosulfan, Thiodan

Endrin

Epichlorohydrin

EPN

Ethion, Nialate

Ethyldichloroarsine

Ethylene bromide

Ethylene cyanohydrin

Ferric arsenate, solid

Ferrous arsenate, solid

Fluorine

Fluoroacetic acid, sodium salt,
compound 1080

Furadan

GB

Guthion

Heptachlor

Hexaethyl tetraphosphate mixture

Hydrocyanic acid solutions

Lead

Lead acetate

Lead arsenate, solid

Lead arsenite, solid

Lead carbonate

Lead cyanide

Lead oxide

Lewisite

London purple, solid

Magnesium arsenate, solid

Magnesium arsenite

Manganese arsenate

Manganese methylcyclopentadienyl-
tricarbonyl

Mercury or Mercurial liquid

Mercuric acetate

Mercuric-ammonium chloride, solid

Mercuric benzoate, solid

Mercuric bromide, solid

Mercuric chloride

Mercuric cyanide, solid

Mercuric iodide, solid or solution

Mercuric oleate, solid

Mercuric oxide (red), solid

Mercuric oxide (yellow), solid

Mercuric oxycyanide, solid

Mercuric-potassium cyanide, solid

Mercuric-potassium iodide, solid

Mercuric salicylate, solid

Mercuric subsulfate, solid

Mercuric sulfate, solid

Mercuric thiocyanate, solid

Mercurol (mercury nucleate), solid

Mercurous bromide, solid

Mercurous gluconate, solid

Mercurous iodide, solid

Mercurous nitrate, solid

Mercurous oxide (black), solid

Mercurous sulfate, solid

Mercury

Mercury acetate, solid

Mercury bisulfate, solid

Mercury compounds (organic)

Mercury cyanide, solid

n-Methylaniline

Methyl bromide and chlorpicrin mixture

Methyl bromide and ethylene dibromide mixture

Methyl bromide, liquid

Methyl chloromethyl ether

Methyldichlorarsine

4,4'-Methylene bis (2-Chloroaniline), Moca

Methyl parathion, liquid

Methyl parathion mixture, dry or liquid

Mevinphos, Phosdrin

Monochloroacetone, stabilized

alpha-Naphthylamine

beta-Naphthylamine

Nickel antimonide

Nickel arsenide

Nickel cyanide, solid

Nickel selenide

Nicotine hydrochloride

Nicotine, liquid

Nicotine salicylate

Nicotine sulfate, liquid or solid

Nicotine tartrate

Nitroaniline

Nitrobenzol, liquid

Nitrochlorbenzene, ortho, liquid

4-Nitrodiphenyl

Nitrogen mustard

4-Nitrophenol

n-Nitrosodimethylamine

Nitroxylol

Oxalic acid

Paranitroaniline, solid

Parathion, liquid

Parathion, mixture, dry or liquid

Paris green, solid

PCB

Pentachlorophenol

Perchloroethylene

Perchloro-methyl-mercaptan

Perchloryl fluoride

Phenol

Phenyldichlorarsine, liquid

Phenylhydrazine hydrochloride

Phorate, Thimet

Phosgene

Phosphamidon, Dimecron

Phosphine

Potassium arsenate, solid

Potassium arsenite, solid

Potassium bifluoride

Potassium binoxalate

Potassium fluoride

beta-Propiolactone

Selenious acid, and salts

Selenium

Selenium fluoride

Schradan, OMPA

Sodium arsenate, solid

Sodium arsenite, liquid

Sodium azide

Sodium bifluoride

Sodium cacodylate, solid

Sodium chromate

Sodium dichromate

Sodium fluoride

Sodium thiocyanate

Strontium arsenite, solid

Strychnine and salts, solid

Sulfur, mustard

Sulfuryl fluoride

2,4,5-T

Tetrachloroethane

Tetraethyl dithio pyrophosphate,
liquid

Tetraethyl dithio pyrophosphate,
mixture, dry or liquid

Tetraethyl lead, liquid

Tetraethyl pyrophosphate, liquid

Tetraethyl pyrophosphate, mixture

Tetramethyl lead

Thallium

Thallium salts, solid

Thallium sulfate, solid

Thiocarbonyl-chloride

Thionazin, Zinophos

Thiophosgene

o-Toluidine

Trichloroethane

Trichloroethylene

VX

Zinc arsenate

Zinc arsenite, solid

Zinc cyanide

(2) Corrosive or Irritant

Acetyl chloride

Acridine

Allyl chlorocarbonate

Allyl chloroformate

Allyl trichlorosilane

Ammonium hydroxide

Ammonium sulfide

Amyl trichlorosilane

Anisoyl chloride

Antimony pentachloride

Antimony pentafluoride

Benzene phosphorous dichloride

Benzoyl chloride

Benzyl bromide

Benzyl chloride

Benzyl chlorformate

Boron chloride

Boron trichloride

Bromic acid

Bromine

Bromine pentafluoride

Bromine trifluoride

Butyl trichlorosilane

Caustic potash, liquid

Caustic soda, liquid

Chloracetyl chloride

Chlorine trifluoride

Chlorosulfonic acid

Chlorosulfonic acid-sulfurtrioxide
    mixture

Chromyl chloride

Cupriethylene-diamine solution

Cyclohexenyl trichlorosilane

Cyclohexyl trichlorosilane

o-Dichlorobenzene

p-Dichlorobenzene

Diethyl dichlorosilane

Difluorophosphoric acid, anhydrous

Dimethylsulfate

Diphenyl dichlorosilane

Dodecyltrichlorosilane

Ethyl chloroformate

Ethyl phenyl dichlorosilane

Fluorosulfonic acid

Formic acid

Hexadecyl trichlorosilane

Hexafluorophosphoric acid

Hexamethylene diamine solution

Hexyl trichlorosilane
Hydrazine
Hydriodic acid
Hydrobromic acid
Hydrochloric acid
Hydrofluoric acid
Hydrofluorosilicic acid
Hydrogen peroxide
Hypochlorite solutions containing more than 7% available chlorine
Iodine monochloride
Isopropyl percarbonate stabilized
Memtetrahydrophthalic anhydride
Methyl chloroformate
Monochloroacetic acid, liquid
Monofluorophosphoric acid, anhydrous
Nitric acid
Nitrohydrochloric acid
Nonyl trichlorosilane
Octadecyltrichlorosilane
Octyl trichlorosilane
Oleum
Perchloric acid
Phenyl trichlorosilane
Phosphoric acid
Phosphorous oxybromide
Phosphorous oxychloride
Phosphorous tribromide
Phosphorous trichloride
Potassium oxalate
Propyl trichlorosilane
Pyrosulfuryl chloride
Silicon chloride
Silicon tetrachloride
Sodium aluminate liquid
Sodium chlorite solution
Sodium oxide
Sodium sulfide
Stannic chloride
Sulfur chloride
Sulfur trioxide, stabilized
Sulfuric acid
Sulfurous acid
Sulfuryl chloride
Thionyl chloride
Thiophosphoryl chloride
Tin tetrachloride, anhydrous
Titanium sulfate solution
Titanium tetrachloride
Tris (1-aziridinyl) phosphine oxide
Vanadium oxytrichloride
Vanadium tetrachloride
Zinc chloride

(3) Flammable

Acetaldehyde

Acetone

Acetonitrile

Acetyl benzoyl peroxide

Acetyl peroxide

Acrolein, inhibited

Acrylonitrile

Alkyl aluminum halides

Allyl bromide

Allyl chloride

Aluminum nitrate

Aluminum phosphide

Ammonium bichromate

Ammonium nitrate

Ammonium nitrate-carbonate mixtures

Ammonium perchlorate

Ammonium persulfate

Ammonium permanganate

Amyl acetate

Amyl chloride

Amyl mercaptan

Amyl nitrite

Antimony pentasulfide

Barium azide, 50% of more water, wet

Barium chlorate, dry or wet

Barium nitrate

Barium perchlorate

Barium permanganate

Barium peroxide

Benzene

Benzine

Benzoyl peroxide

Butyl acetate

Butyl mercaptan

Butyl aldehyde

Calcium chlorate

Calcium chlorite

Calcium hypochlorite, compounds,
dry, containing more than
39% available chlorine

Calcium metallic

Calcium nitrate

Calcium permanganate

Calcium peroxide

Calcium phosphide

Calcium resinate

Caprylyl peroxide solution

Carbon bisulfide

Chlorate of potash

Chlorate of soda

Chlorine dioxide

Chlorobenzene

Chlorobenzoyl peroxide

Chromic acid

Chromic anhydride

Cobalt nitrate

Cobalt resinate, precipitated

Collodion

Copper nitrate

Crotonaldehyde

Cumene hydroperoxide

Cyclohexane

Cyclohexanone peroxide

Cyclopentane

Cyclopentane, methyl

Decaborane

Diborane

Dichlorethylene

Dichloroisocyanuric acid, dry,
containing more than 39%
available chlorine

1,2-Dichloropropane

Dicumyl peroxide

Diethylamine

Diisopropylbenzene hydroperoxide

Dimethylamine, aqueous solution

Dimethyldichlorosilane

Dimethylhexane dihydroperoxide

Dimethyldydrazine

Dimethylsulfide

Dioxane

Ether

Ethyl acetate

Ethyl chloride

Ethyl dichlorosilane

Ethylene dichloride

Ethyleneimine, inhibited

Ethylene oxide

Ethyl formate

Ethyl mercaptan

Ethyl methyl ether

Ethyl methyl ketone

Ethyl nitrate

Ethyl nitrite

Ethyl trichlorosilane

Gasoline

Guanidine nitrate

Hafnium metal, dry

Heptane

Hexane

Isooctane

Isooctene

Isopentane

Isoprene

Isopropanol

Isopropyl acetate

Isopropyl ether

Isopropyl mercaptan

Isopropyl percarbonate, unstabilized

Lauroyl peroxide

Lead nitrate

Lithium aluminum hydride

Lithium aluminum hydride, ethereal

Lithium amide, powdered

Lithium ferro silicon

Lithium hydride

Lithium hypochlorite compounds, dry
containing more than 39%
available chlorine

Lithium metallic

Lithium peroxide

Lithium silicon

Magnesium chlorate

Magnesium nitrate

Magnesium perchlorate

Magnesium peroxide, solid

Mercuric nitrate

Methyl acetate

Methyl acetone

Methyl aluminum sesquibromide

Methyl aluminum sesquichloride

Methyl chloride

Methyl chloromethyl ether, anhydrous

Methyl dichlorosilane

Methyl ethyl ketone

Methyl formate

Methyl hydrazine

Methyl iso-propenyl ketone, inhibited

Methyl magnesium bromide in ethyl
ether in concentrations not
over 40%

Methyl mercaptan

Methyl methacrylate monomer

Methyl trichlorosilane

Methyl vinyl ketone, inhibited

Monoethylamine, aqueous solution

Naptha

Neohexane

Nickel carbonyl

Nickel catalyst, finely divided
Nitro carbo nitrate
Paramethane hydroperoxide
Pentaborane
Pentane
Pentane, methyl
Peracetic acid
Permanganate of potash
Permanganate of soda
Petroleum ether
Phosphoric anhydride
Phosphorus, amorphous, red
Phosphorus pentachloride
Phosphorus pentasulfide
Phosphorus sesquisulfide
Phosphorus, white or yellow
Picric acid, wet
Potassium bromate
Potassium dichloroisocyanurate, dry, containing more than 39% available chlorine
Potassium dichromate
Potassium, metallic
Potassium nitrate
Potassium nitrate mixed with sodium nitrate
Potassium nitrite
Potassium perchlorate
Potassium permanganate
Potassium peroxide
Potassium sulfide
Propylene imine, inhibited
Propylmercaptan
Propylene oxide
Pyridine
Pyroxylin plastics
Silver nitrate
Sodium aluminum hydride
Sodium amide
Sodium bromate
Sodium carbonate peroxide
Sodium chlorate
Sodium chlorite
Sodium dichloroisocyanurate, dry containing more than 39% available chlorine
Sodium hydride
Sodium hydrosulfite
Sodium, metallic
Sodium, metallic, dispersion in organic solvent
Sodium methylate, dry

Sodium nitrate

Sodium nitrite

Sodium nitrite mixed with potassium nitrate

Sodium permanganate

Sodium peroxide

Sodium picramate, wet

Sodium potassium alloys

Spirits of nitroglycerin

Strontium chlorate, wet or dry

Strontium nitrate

Strontium peroxide

Succinic acid peroxide

Tertiary butylisopropyl benzene hydroperoxide

Tetrahydrofuran

Tetranitromethane

Thorium metal, powdered

Titanium metal powder, dry

Titanium metal powder, wet

Toluol

Trichloroborane

Trichloroisocyanuric acid, dry, containing more than 39% available chlorine

Trichlorosilane

Trimethylamine, aqueous solution

Trimethylchlorosilane

Trinitrobenzene, wet

Trinitrobenzoic acid, wet

Trinitrotoluene, wet

Uranyl nitrate, solid

Vinyl acetate

Vinylidene chloride, inhibited

Vinyl trichlorosilane

Wet nitrocellulose

Wet nitrostarch-20% water

Wet nitrostarch-30% solvent

Wood alcohol

Zinc ammonium nitrite

Zinc chlorate

Zinc ethyl

Zinc nitrate

Zinc permanganate

Zinc peroxide

Zirconium metal

Zirconium, metallic, solutions

Zirconium picramate, wet

Zirconium scrap

(4) Strong Sensitizer

Epoxy resin systems containing in any concentration, ethylenediamine, diethylenetriamine, and diglycidyl ethers of molecular weight of less than 200.

Formaldehyde and products containing .1 percent or more of formaldehyde.

Glutaraldehyde

Oil of bergamot and products containing 2 percent or more of oil of bergamot.

Paraphenylenediamine and products containing it.

Powdered orris root and products containing it.

Toluene 2,4 - Diisocyanate

Waste epoxy resins

(5) Pressure generating material through decomposition, heat or other means

Ammonium chromate

Antimony trisulfide

1,2,4-Butanetriol trinitrate

Cadmium nitrate

Calcium carbide

Calcium hydride

Chlorine pentafluoride

Copper acetylide

Copper chlorotetrazole

Cyanuric triazide

Diazodinitrophenol

Diethylene glycol dinitrate

Dipentaerythriotol hexanitrate

Fulminate of mercury

Glycerolmonolacetate trinitrate

Glycol dinitrate

Gold fulminate

Guanyl nitrosamino guanylidene
    hydrazine

Hydrazine azide

Hydrazoic acid

Lead azide

Lead chlorite

Lead 2,4-Dinitrorescorcinate

Lead monomitroresorcinate

Lead styphnate

Mannitol hexanitrate

Nickel nitrate

Nitroglycerin

Nitromannite

Nitrosoguanidine

Pentaerythrite tetranitrate

Polyvinyl nitrate

Potassium dinitrobenzfuroxan

Silver acetylide

Silver azide

Silver styphnate

Silver tetrazene

Sodium perchlorate

Tetrazene

Vinyl chloride

60121. Wastes Not Listed. A waste will be considered hazardous if it meets the definition given in Section 25117 of the Health and Safety Code even though said waste is not listed in Section [illegible]

Article 3. Extremely Hazardous Waste

60130. Extremely Hazardous Waste. The following is a listing of the hazardous wastes as listed in Section 60120 which have been determined based on their toxicities to be extremely hazardous as defined in Section 25115 of the Health and Safety Code:

Acrolein, Aqualin
2-Acetylaminofluorene
Aldrin
Aluminum phosphide, Phostoxin
4-Aminodiphenyl
Arsines
Benzidine, and salts
Beryllium
Bidrin
Bomyl
Boranes, Di-, penta-, trichloro-
Carbanolate, Temik
Carbophenothion, Trithion
Chloroacetaldehyde
Compound 4072
Cyanide salts
Cycloheximide, Acti-dione
DDVP, dichlorvos, vapona
Demeton, Systox
Dichlorobenzidine
Diglycidyl ether
Dimethylaminoazobenzene
Dimethylsulfate
Dinitrocresol, Sinox, Elgetol
Dinitrophenol
Dioxathion, Delnav
Disulfoton, Disyston
Dowicide 7, PCP, Penchlorol
Endosulfan, Thiodan
Endrin
EPN
Ethion, Nialate
Ethyleneimine
Fluorine
Fluoroacetic acid, sodium salt,
compound 1080
Furadan
Hydrocyanic acid, Hydrogen cyanide
Hydrofluoric acid, hydrogen fluoride
Lead arsenate

Mercury

Methyl chloromethyl ether

4,4'-Methylene bis (2-chloroaniline), Moca

Methyl parathion

Mevinphos, Phosdrin

alpha-Naphthylamine

beta-Naphthylamine

Nickel carbonyl

4 - Nitrodiphenyl

n - Nitrosodimethylamine

Parathion

Phorate, Thimet

Phosgene

Phosphamidon, Dimecron

Phosphine

Phosphorus, white or yellow

beta-Propiolactone

Selenious acid, and salts

Selenium fluoride

Strychnine, and salts, except

[illegible]

Tetraethyl lead, and other organic lead

Tetraethyl pyrophosphate, TEPP

Tetraethyl dithio pyrophosphate

Tetranitromethane

Thionazin, Zinophos

60131. **Hazardous Wastes Not Listed.** A hazardous waste will be considered extremely hazardous if it meets the definition given in Section 25115 of the Health and Safety Code even though said hazardous waste is not listed in Section 60130.

66134. Disposal. (a) No extremely hazardous waste shall be disposed of in California except at an eligible disposal site acceptable for such waste as defined in Subchapter 15, commencing with Section 2500 of Title 23 of the California Administrative Code and as approved by the Department.

(b) No person shall dispose of a waste material which he may reasonably consider to be an extremely hazardous waste without prior approval of the Department. Requests for approval shall be sent to the Department by certified mail at least fifteen (15) days prior to the intended date(s) of disposal of such waste material. Such notification shall include, but not be limited to, data on amount and type of material, date(s) of intended disposal and the proposed disposal site. The Department shall reply by Certified Mail within ten (10) days of the receipt of notification, either granting approval of the proposed disposal method or detailing alternate acceptable methods. In the event that notification to the Department fifteen (15) days prior to the intended date(s) of disposal is impracticable or results in undue hardships, the Department may, upon request, waive this requirement.

(c) In the event of an emergency, accident, or disaster which results in a need for the immediate processing or disposal of an extremely hazardous waste, the required fifteen (15) day notification shall be waived. As soon as possible thereafter, the Department shall be notified first by telephone or telegraph and subsequently by certified mail as to the amount and type of the extremely hazardous waste and the processing or disposal method used. If the method of processing or disposal of the extremely hazardous waste is not acceptable to the Department, subsequent action may be required to re-process or remove and re-dispose of the extremely hazardous waste. If this action is necessary, the Department will reply within one working day after receiving notification.

(d) The Department may grant blanket approval up to twelve (12) months for processing and disposal methods for reoccurring waste material.

(e) Hazardous wastes being legally disposed of directly to sanitary sewers are exempt from these regulations.

Article 4. Waste Mixtures

60140. **Hazardous Waste Mixtures.** For a mixture of wastes, the determination of whether the mixture is a hazardous waste as defined by Section 25117 of the Health andSafety Code should be based on the physical, chemical and pharmacological characteristics of the mixture. A mixture of wastes may therefore be less hazardous or more hazardous than its components because of synergistic or antagonistic reactions. It may not be possible to reach a decision concerning the toxic, irritant, corrosive, flammable, sensitizing or pressure-generating properties of a waste from what is known about its components or ingredients. The mixture itself shall then be tested by the producer and the analytical data shall be submitted to the Department for determination as to whether the mixture is hazardous.

Article 5. Transportation

60150. Manifest Form and Content. The forms approved by the State Water Resources Control Board for the records to be maintained by waste haulers, as defined in Subchapter 13 (commencing with Section 2400) of Title 23 of the California Administrative Code, shall serve as the manifest pursuant to Section 25162 of the Health and Safety Code. The form and content of the State Water Resources Control Board's California Liquid Waste Haulers Record shall satisfy the requirements of Section 25161 of the Health and Safety Code.

Article 6. Records

60170. Records. Operators of disposal sites which receive hazardous waste shall submit monthly records to the director as follows:

(a) An accounting of the fees collected.

(b) A copy of the manifests received. Said manifest shall include, but need not be limited to, the type, quantity and the final disposal method of the waste, whether by ponding, spreading, landfill, or other.

(c) A summary of the deviations from the standard operating procedure. The summary shall include a brief description of the deviations and reasons therefor.

Article 7. Fees

60180. Fees. Pursuant to Section 25174 of the Health and Safety Code, fees will be collected by the operator of any disposal site that receives hazardous waste. Said fees, based on the schedule below, shall be paid to the director. Such fees shall be deposited each month in the Hazardous Waste Control Account in the General Fund.

For liquids, slurries, sludges, and other hazardous materials, either bulk or containerized, a fee of one dollar ($1.00) shall be collected for all loads of one (1) ton or less. For loads in excess of one (1) ton, a fee not to exceed sixty cents ($0.60) per ton shall be collected, provided the total fee equals or exceeds one ($1.00) dollar.

In the event scales are not available at the processing facility or disposal site, an equivalent fee schedule may be levied based on volumetric measurements or other means as approved by the Department.

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